SOUTH CAROLINA
WATER RESOURCES COMMISSION
GEOLOGY-HYDROLOGY DIVISION

INVESTIGATION OF GROUND-WATER PROBLEMS NEAR THE VULCAN MATERIALS MARBLE QUARRY CHEROKEE COUNTY, SOUTH CAROLINA

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Contents

Figures

Table

EXECUTIVE SUMMARY

Citizen complaints about wells drying up and having poor water quality due to blasting at a marble quarry prompted the Office of the Lieutenant Governor to request the South Carolina Water Resources Commission (SCWRC) to conduct an investigation. Since January of 1986 the Piedmont Office of the SCWRC has been conducting a study in the vicinity of the quarry. The study area is in northeastern Cherokee County, approximately 5 miles north of Blacksburg. About 210 people live in the 1.2 square-mile area that contain a trailer park, houses, farmland, and the Vulcan Materials marble quarry.

The quarry is situated on a portion of an elongated marble body that trends northeast-southwest through the area. The geology of the area is characterized by intensely folded and faulted rocks which greatly influence ground water properties. Wells are generally of medium to low yield and water quality is generally good.

The Piedmont SCWRC Office set out on the following objectives:

1. To identify problems that local residents are experiencing.
2. To evaluate the extent of the problems.
3. To determine the cause(s) of these hydrologic problems.
4. To present recommendations.

Water levels were measured in 31 wells during March of 1986 to construct a water table map. Automatic data recorders were installed on two deep wells to monitor water levels continuously. Blasting records and other information were obtained from the quarry.

The following conclusions were reached:

1. Problems: Several residents complained that after blasting at the quarry their wells would dry up temporarily or the water would become silty or have an "iron taste". A more common complaint was that of ground vibration from the blasting, in some cases causing structural damage to houses and/or wells.
2. Extent: An estimated 60 families live in the general area and 37 of these were contacted by the SCWRC. 54 wells were inventoried and descriptions of problems were taken from residents. Of the wells inventoried, 59 percent have had water problems. Of those wells with problems, 19 percent were solved by drilling new wells or installing water filters. Of the seven families still having problems, five have water quantity and quality problems while two have only water quality problems.
3. Causes of hydrologic problems:
    a. Topographic and drainage modifications by the quarry resulted in lowering of the water table and a reduced ground-water recharge area. These changes proved critical for wells upgradient from the quarry.
    b. Water quality has been adversely affected in ungrouted wells which allow loose material along the wellbore to travel down the outside of the well casing and enter the well hole after blasting or rainfall.

4. Recommendations:

a. Drilled wells are recommended for sites in the trailer park. Technical advice should be sought from SCWRC or other agencies for site selection.

b. Water filters and metal pressure tanks should be used to reduce suspended sediment, and old wells and pumps should be cleaned regularly.

c. New wells should be carefully developed to increase yield and improve water quality, and they should be carefully grouted. Surface cement pads should also be installed to protect wells from surface water contamination.

d. The quarry should monitor and report water flow in its pit pumps, restore vegetative cover to reduce runoff and increase infiltration, and maintain a constant flow of water in its diversion channels to protect the local water table.

e. People with water problems at the south end of the trailer park should consider drilling new wells. Their wells are going dry and eventually will not yield sufficient water to meet their water demands. Drilled wells are preferred as bored wells may not be deep enough to accomodate declines in the water table.

f. Packer tests of existing wells, at an appropiate interval the length of each well, to determine hydraulic properties of the subsurface.

g. Monitor other wells around the mine to determine if blasting has any impacts on ground water at preferred orientations.

h. Well owners should monitor water levels monthly to determine water level fluctuations.

i. If possible, well owners should evaluate their pump horse power and yield for the depth to water. They should determine how their yield will decrease for various increases in water table depth.

INTRODUCTION

The South Carolina Water Resources Commission, as requested by the Office of the Lieutenant Governor, investigated ground-water problems in the vicinity of the Vulcan Materials Marble Quarry near Blacksburg, S.C.

Residents of the area have complained about several problems in the area supposedly caused by the operation at the nearby quarry. These problems range from physical damage to structures to disruption of the ground-water supply.

Purpose and scope of investigation

The purposes of this study are to identify and evaluate problems and to recommend possible solutions. In scope, this study addresses the hydrogeologic problems in their relation to the quarrying operation.

Objectives

The objectives of this project are:

1. To identify hydrologic problems that residents are experiencing.
2. To evaluate the extent of the problems.
3. To identify the cause(s) of the problems.
4. To present recommendations.

AREA OF STUDY

The area of study is located in the northeast corner of Cherokee County, Figure 1. It is approximately 5 miles northeast of Blacksburg. The area is delimited by Interstate Highway 85 on the north, Antioch Church Road on the south, east boundary road to the east, and U.S. Highway 29 on the west (Figure 2).

An estimated population of 210 is unevenly distributed over a 1.2 square-mile area. The area could be divided into four types of land use:

1. Residential: 10 percent of the area. Residences are located in the northern and southwestern parts of the study area.

2. Trailer park: 15 percent of the area. It is developing along a gravel road off U.S. Hwy 29.

3. Vulcan Quarry: 23 percent of the area. It is located on the east side.

4. Farms: 52 percent of the area. Farms occupy most of the land area and are located in the south.

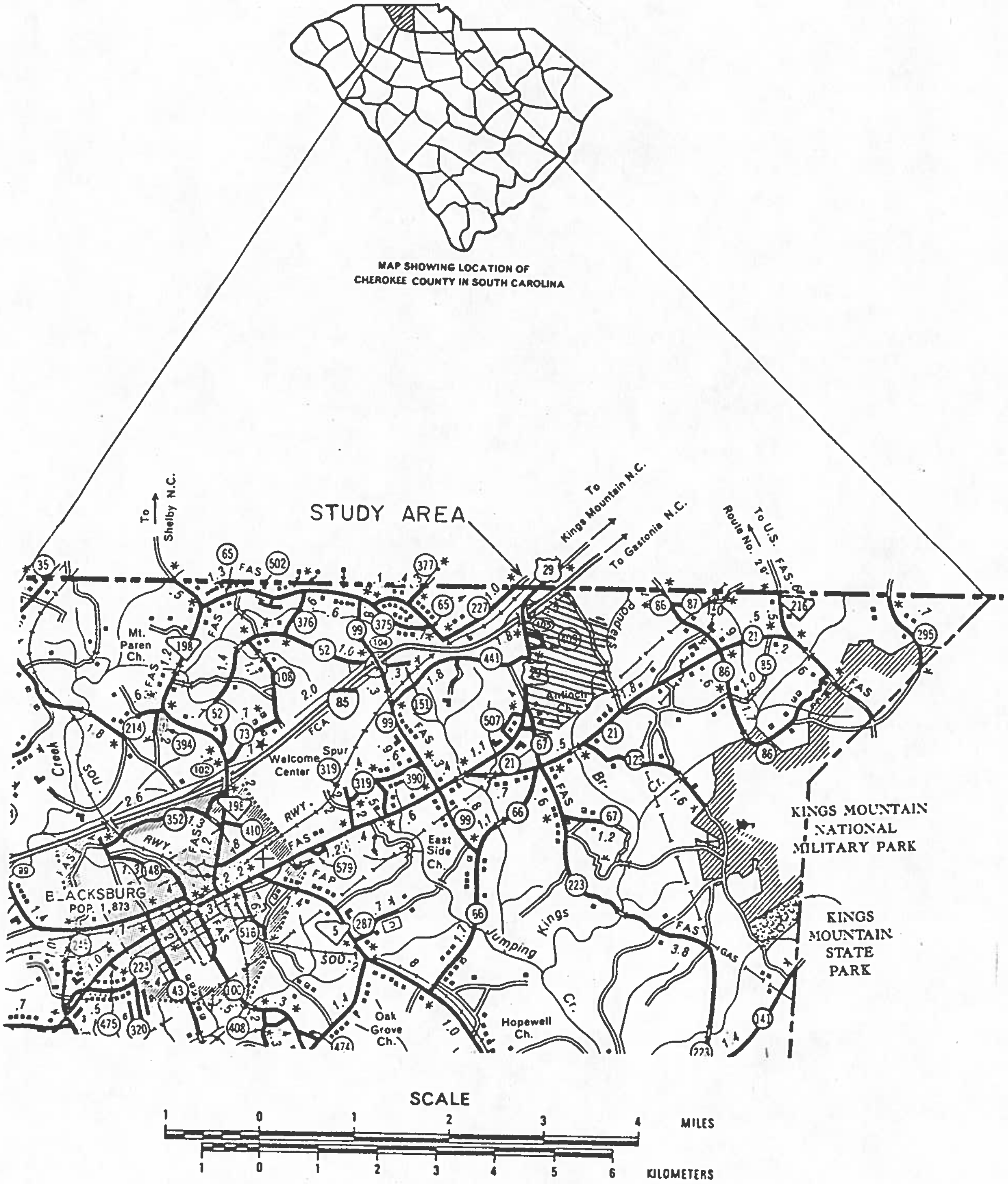


Figure 1. Location of study area.

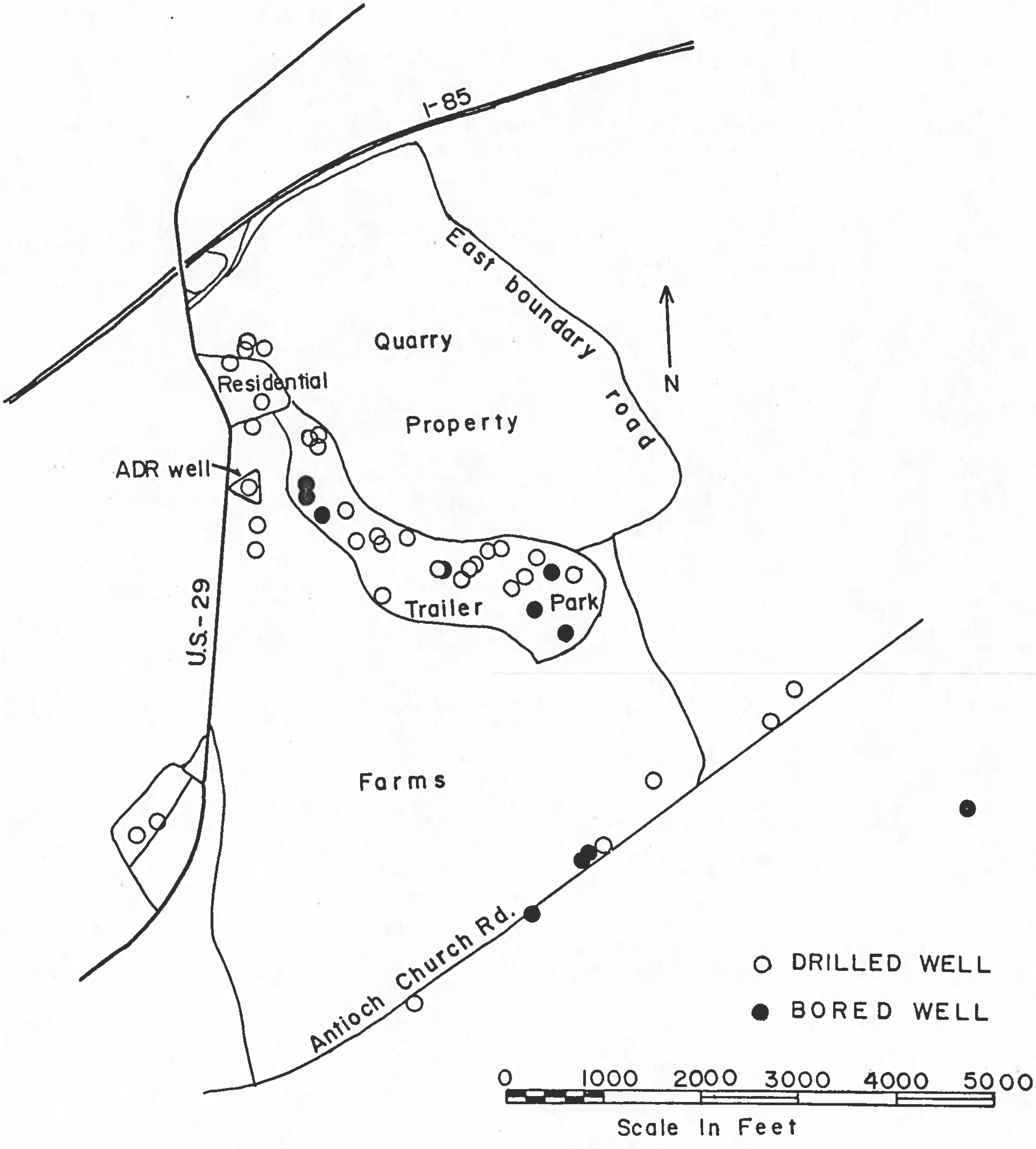


Figure 2. Land use distribution within study area.

REGIONAL GEOLOGY

Cherokee County is in the Piedmont Physiographic Province and is underlain by rocks of the Inner Piedmont belt in the west and north, the Kings Mountain belt in the center and northeast, and the Charlotte belt in the south (Figure 3). These units all strike generally northeast, with most dips ranging from moderate to steep or even vertical.

The Inner Piedmont belt is composed of rocks of low- to high-grade metamorphic rank, generally having moderate dips, which are dominantly gneisses, schists, amphibolites, and intrusive granitoid bodies (Goldsmith, 1981, p. 19-20).

The Kings Mountain Shear Zone, a major discontinuity that separates the Inner Piedmont belt to the northwest from the Kings Mountain belt to the southeast, is a steeply dipping fault that may be part of a system more than 340 miles long (Horton, 1981, p. 12, and Horton and Butler, 1981, p. 203). Kings Mountain belt rocks of the area are dominantly metasedimentary and metavolcanic with steep dips and lower metamorphic grade than rocks of the belts adjacent to them.

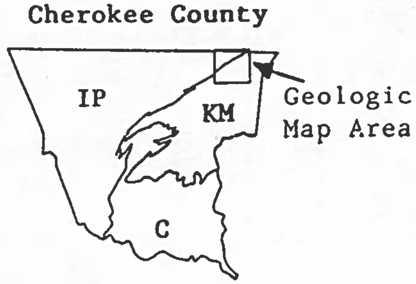
To the southeast is the Charlotte belt, which is characterized by rock types similar to those of the Kings Mountain belt but of higher metamorphic grade; several intrusive rock bodies are also present.

Nearly vertical diabase dikes strike N40°-50°W, perpendicular to the strike of the northeast-trending dominant rock units. These dikes range in thickness from a few inches to several feet (up to 50 ft), and the largest is 8 miles long (Horton, 1981, p. 10). The dikes intruded during rifting of the region, after the other major deformational events that shaped the structure of the Piedmont (Horton, 1977, p. 168).

Geology of the Study Area

Most of the study area is located within the Kings Mountain belt, but the northwest corner is in the Inner Piedmont belt. The Vulcan Materials marble quarry is situated astride a 300-ft thick bed of the Gaffney Marble. Strike and dip of the marble are about N73°E and 45° to the NNW. The marble includes minor amounts of amphibolite and it interfingers with sericite schist or phyllite on either side (Horton and others, 1981, p. 220). Parallel to the marble and surrounded by the sericite schist/ phyllite are beds of quartzite, and to the southeast of the quarry is another marble unit parallel to the first one (Horton, 1977, p. 21-23).

To the southeast of this marble unit is more sericite schist/phyllite and quartzite. Parallel to and extending southwest from the quartzite is the Blacksburg Shear Zone, which separates the sericite schist/phyllite from a unit of metatrondhjemite. This unit and the sericite schist/ phyllite southeast of the quartzite lie along the northeast-plunging axis of the Cherokee Falls Synform. The synform is apparently truncated by the inferred Kings Creek Shear Zone to the southeast (Horton, 1977, p. 13, and Horton, 1981, plate 1). Approximately one-third of a mile northwest of the quarry the Kings Mountain Shear Zone strikes parallel to the general northeast trend. It separates phyllites of the Kings Mountain belt from schists and gneisses of the Inner Piedmont belt.



IP	Inner Piedmont belt
KM	Kings Mountain belt
C	Charlotte belt

KMSZ	Kings Mountain Shear Zone
BBSZ	Blacksburg Shear Zone
KCSZ	Kings Creek Shear Zone
CFS	Cherokee Falls Synform

Kings Mountain belt rocks

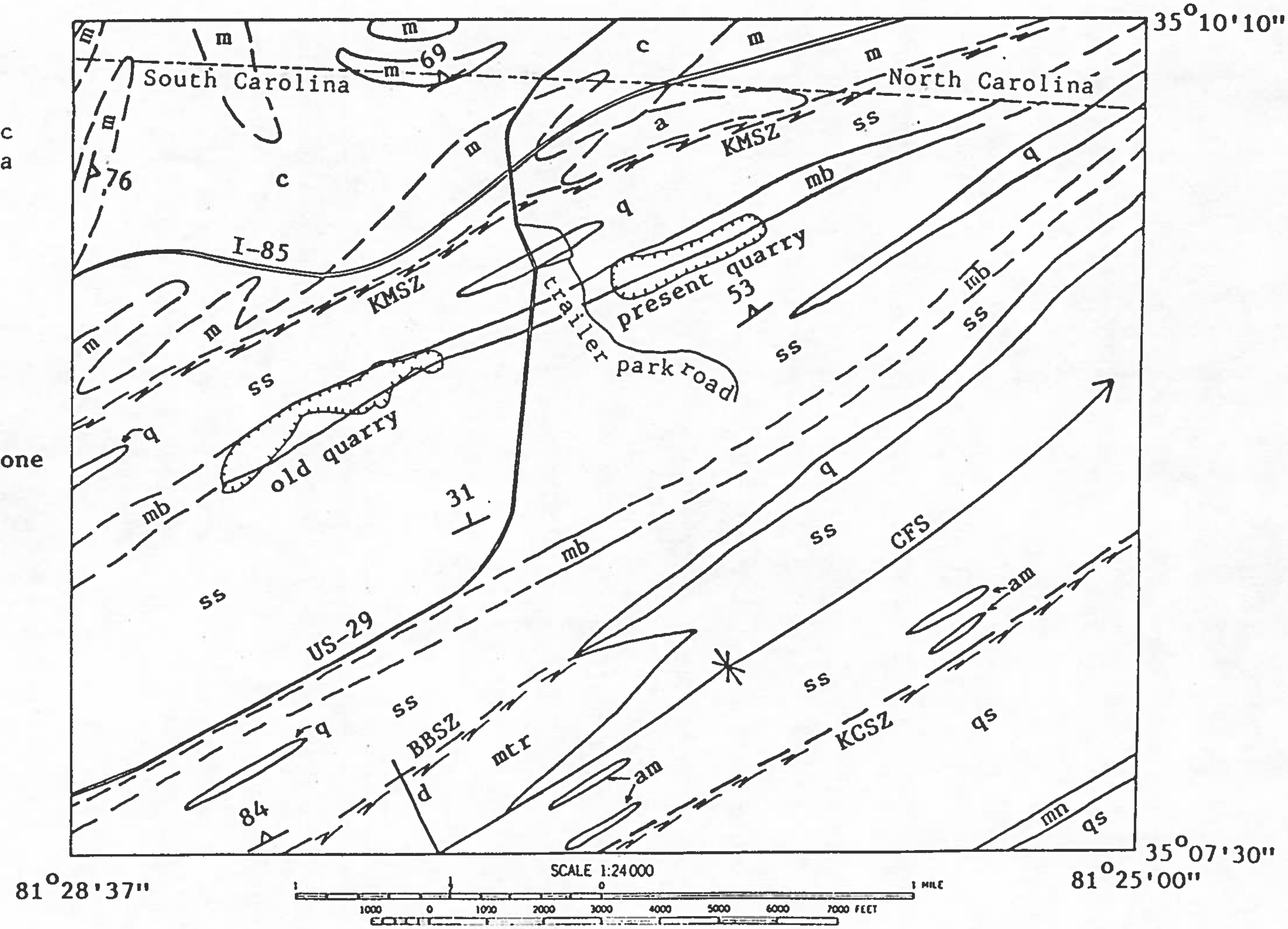
mtr	metatrondhjemite
am	amphibolite
mb	marble
q	quartzite
ss	sericite schist or phyllite
qs	quartz-sericite schist or phyllite
mn	manganiferous schist

Inner Piedmont belt rocks

a	amphibolite
m	white mica schist

Plutonic rocks

d	diabase dike
c	Cherryville Quartz Monzonite



strike and dip of schistosity or foliation
strike and dip of bedding or primary compositional layering
synform, showing trace of axis and direction of plunge
geologic contact, dashed where approximate
shear zone

Figure 3. Geology of study area (from Horton, 1977 and 1981).

Geomorphology

The geomorphology of the area is affected by the various rock types. Narrow ridges of resistant quartzite follow the northeast strike and cause many of the smaller streams to flow southwest or northeast in valleys of less resistant rocks such as marble. Rivers and larger creeks cut across the regional strike and often flow southeast, suggesting partial control by the northwest-southeast striking fracture system intruded by diabase dikes (Horton, 1977, p. 17).

Brittle faults are important in the region; most dip steeply and are clustered in two dominant-trending groups. One group strikes northeast and the other strikes northwest. The northeast-striking faults appear to be related to earlier deformation events than the northwest-striking faults, which may be related to the dike-intruded fractures. Joints mapped in the region are nearly vertical and have a median strike of N49°W, while diabase dikes have a median strike of N37°W and vertical dip (Horton, 1977, p. 75-77).

The regional strike of the rock units and faults, joints, and fractures associated with them are important to the availability of ground water in the region. Also important is the topography, which is influenced by the differential erosion of rocks. This is especially true in the study area where quartzite beds form ridges on either side of the quarry, which lies in a valley formed from more easily weathered marble. Most of the wells in the study area are in the sericite schist or phyllite, but some are in the quartzite; three wells are in the marble unit.

HYDROLOGY

Topography

The study area is made up of low rolling hills cut by several small creeks. The maximum elevation is 900 feet above sea level in the northern part of the study area, and the minimum elevation is 700 feet in the southern part. The northern half of the study area is a valley bounded on the north and south by several knolls that descend in moderate to steep slopes. This valley is underlain by a marble body that runs northeast cutting through the trailer park and the quarry. The southern part of the study area is made up of gentle slopes dissected by several creeks. The average slope is about 3 1/2 percent and is southerly.

Climate

Cherokee County is in the Northwest Climatic Division of South Carolina. The average annual temperature is 60.5°F. The warmest month is July, and the coolest is January. The average annual precipitation is 49 inches (Gaston Shoals Rainfall Station). March is the wettest month and November is the driest.

Severe drought 1981. An analysis of historical data shows that 1981 was a dry year, with the annual precipitation only 70 percent of normal. The annual precipitation was 34.21 inches, whereas the long-term normal is 48.99 inches. The drought from 1949 to 1957 in Cherokee County was much worse in terms of both degree and duration.

Extreme Drought 1985-86. In 1986 South Carolina, especially the Piedmont Region, was affected by one of the worst droughts in the State's history. Precipitation was scarce. In some areas it was as much as 20 inches below normal. In the Blacksburg area, the drought actually started in 1985, with only four months of precipitation greater than normal. The drought continued until late summer 1986, when heavy rains in August curtailed the drought. These factors adversely affected the hydrologic resources of the State and worsened situations such as the one addressed in this study.

Drainage Basin

Two intermittent streams, one from the west and one from the north, join in the northeastern part of the study area to form the perennial Mill Creek. This stream formerly flowed southeast but presently is dammed. A diversion channel beginning in this lake runs west along the north side of the quarry pit, then south between the trailer park and the quarry, and finally meets the original course of Mill Creek. From there Mill Creek flows southwest, is joined by one intermittent stream from the northeast, then by two others from the northwest, and just before leaving the study area it turns sharply southeast.

Water Table

A ground-water map (Figure 4) has been drawn from data collected during the second half of March 1986. Control points are domestic wells used as drinking water supply. These wells were located on a 20-foot contour map to create the ground-water map. Basically two ground-water basins exist, largely the result of topography but modified by the mine pit. The resistant ridge on the north and one through the central portion of the study area create the northern basin. This basin is further accentuated by the quarry which has lowered the local water table, inducing ground-water flow towards the pit from all sides.

The valley of Mill Creek, between the middle-area ridge and the ridge to the south, make up the southern basin. Ground-water flow is primarily towards the creek and downstream.

Analysis of the well data indicates that the hydraulic head in the saprolite is similar to the head in the crystalline rock; therefore, if water-table conditions are assumed in the rock aquifer, then the well yields are dependent on local recharge and are largely influenced by geological trends.

Ground-Water Recharge

In the study area, as well as throughout most of the Piedmont Province, ground water is recharged by precipitation and discharged to streams and springs (Stewart, 1964). If it is assumed that the drainage-basin boundaries represent the ground-water recharge boundaries then from the 49 inches of annual precipitation over the study area drainage basin, it could be assumed that 19 percent (Daniel and Sharpless, 1983) or 0.54 mgd (million gallons per day) becomes ground-water recharge. This is potential ground water available for withdrawal. However, a large percentage of this volume is discharged into the streams and only a portion of it can be used as water supply (Figure 5). The reason for this is the low hydraulic conductivity (ability of soil to transmit water) of the saprolite and the even lower hydraulic conductivity of the bedrock. As noted in the figure, however, the thicker the saprolite, the greater will be the available water storage.

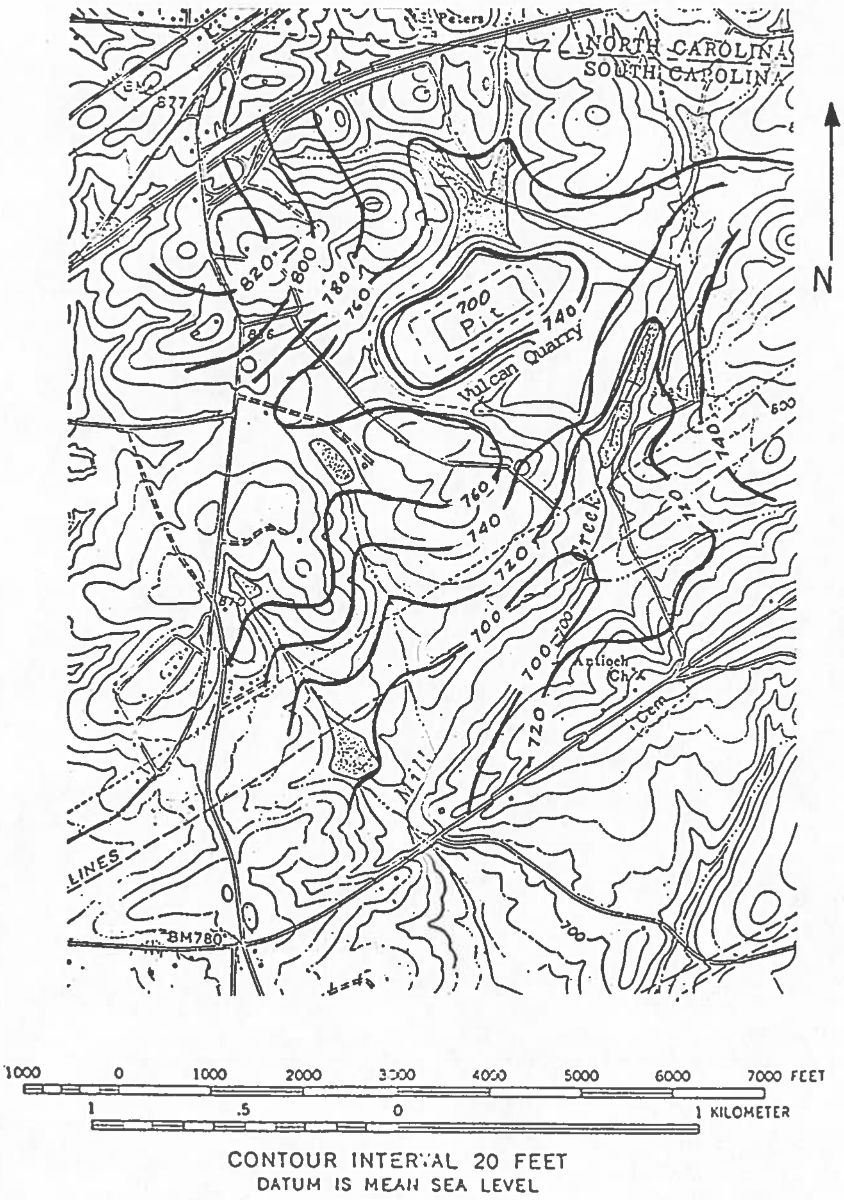
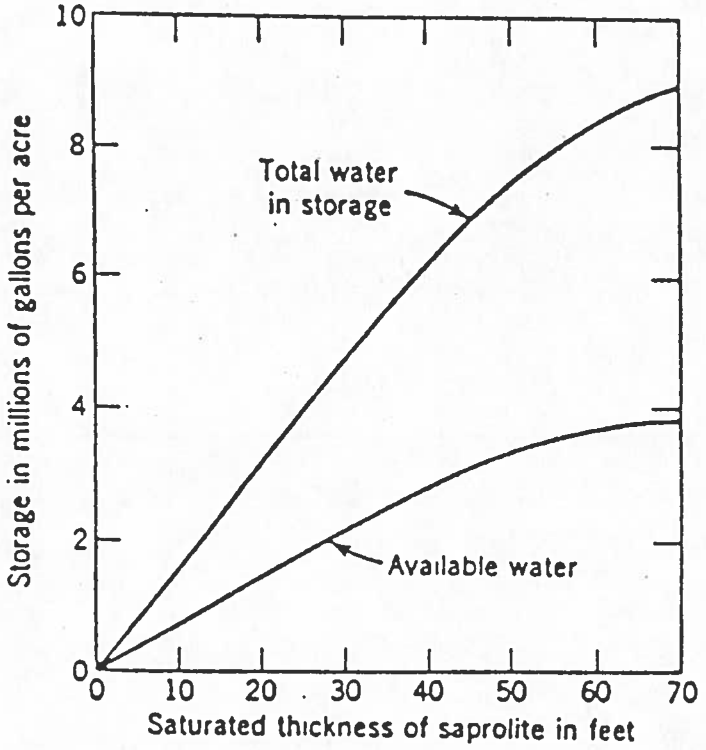


Figure 4. Water-table contours, March 1986.



From Stewart, J.W., 1962

Figure 5. Available water in the saprolite as determined from core samples.

PREVIOUS INVESTIGATIONS

On March 25, 1980, Philip Berger & Associates, Inc. conducted a vibration and sound study for the Vulcan Materials Company. The purpose of this study was to determine the possible effects of blasting at the quarry on structures in the area. The consulting firm concluded from measurements of vibration and air pressure that blasts could not cause damage. Moreover, the firm concluded that the lowering of the water table at Antioch Church was not caused by blasting.

On May 6, 1985, the same company, again on behalf of the quarry, conducted another study to determine possible effects on structures in the vicinity of the quarry. They concluded, once more, that the ground motion and airblast levels were within limits recommended by the United States Bureau of Mines.

On October 5 and other dates in 1985, Stanley Clark of the South Carolina Department of Health and Environmental Control (Ground Water Protection Division) made some geophysical logs of a well in the area. Also in October of 1985, Craig Kennedy of the South Carolina Land Resources Conservation Commission conducted a vibration study and a water well survey.

DESCRIPTION AND EXTENT OF THE PROBLEM

The SCWRC Piedmont Regional Office Staff, during the spring of 1986, surveyed the area, inventoried wells, and contacted the Vulcan Quarry staff, residents, and local drillers. Following are the results of that activity:

a. Well inventory. Thirty-seven of the area's 60 families were contacted. A total of 54 wells were inventoried, which include 40 drilled wells, 13 bored wells, and one hand-dug well (Table). The dug well has been included with the bored wells in this report. While most families or individuals were able to drill or bore another well if theirs went dry, three did not; two of these families moved away and another one gets water piped in from a neighbor's well.

Of the 54 wells inventoried, 35 are in use at the present time. The others are either dry or unusable. Thirty-one of the wells are in the trailer park (22 drilled and 9 bored), 15 are in the farm area (11 drilled, 3 bored, and 1 dug), and 8 are in the residential area (7 drilled and 1 bored). The trailer park has the highest percentage of dry or unusable wells, at 42 percent, while 27 percent of the farm area's wells and 25 percent of the residential area's wells are dry and unusable.

Bored and drilled wells are differentiated in the table because of their differences in construction and hydrologic properties.

Drilled wells had a slightly higher percentage of problems (60 percent to 57 percent), but bored wells had fewer problems solved, 0 to 6. Thus the drilled wells appear to be the more reliable wells.

Table. Distribution of well problems by location and well type.

		BORED WELLS				DRILLED WELLS				TOTAL
		PROBLEMS				PROBLEMS				
		quantity	quality	none	Subtotal	quantity	quality	none	Subtotal	Grand Total
TRAILER PARK	Initial problems	1	-		1	5[1]	1[1]		6	7
	Later problems	4	1		5	6	5		11	16
	Total wells with probs	5	1		6	11	6(3)[2]		15[3](3)	21[3]
	Dry or unusable	{4}	-		{4}	{9}	-		{9}	{13}
	No problems			3	3			7	7	10
	Total wells				9				22(3)	31(3)
FARM AREA	Initial problems	-	-		-	1	1		2	2
	Later problems	1	-		1	4	-		4	5
	Total wells with probs	1	-		1	5(1)[4]	1		5[3]	6[3]
	Dry or unusable	{1}	-		{1}	{3}	-		{3}	{4}
	No problems			3[5]	3			6	6	9
	Total wells				4				11(1)	15(1)
RESIDENTIAL AREA	Initial problems	-	-		-	-	-		-	-
	Later problems	1	-		1	3	1		4	5
	Total wells with probs	1	-		1	3(1)[4]	1(1)[2]		4	5
	Dry or unusable	-	-		-	{2}	-		{2}	{2}
	No problems			-	-			3	3	3
	Total wells				1				7(2)	8(2)
TOTAL	Initial problems	1	-		1	6	2		8	9
	Later problems	6	1		7	13	6		19	26
	Total wells with probs	7	1		8	19(2)	8(4)[2]		24[3]	32[3]
	Dry or unusable	{5}	-		{5}	{14}	-		{14}	{19}
	No problems			6	6			16	16	22
	Total wells				14				40(6)	54(6)

Numbers in parentheses indicate number of wells with problems solved. Numbers in brackets are dry wells, included in total problem sums. "Initial problems" are those encountered when drilling or immediately afterwards, such as no water, well collapse, or poor water quality. "Later problems" are those occurring suddenly or gradually at a later time.

Notes:
1. Three quantity and one quality problem were all at one homesite.
2. Filters installed.
3. Some wells had both water quantity *and* quality problems, so there is an overlap of total number of problems.
4. Well redrilled to greater depth.
5. One of these is an old hand-dug well.

Trailer park wells had the highest number and percentage of problems, 21 out of 31 (68 percent), over residential wells, 5 of 8 (63 percent), or farm wells, 6 of 15 (40 percent). In the trailer park, two-thirds of both the bored wells and the drilled wells had problems. Three of the drilled-well problems were solved compared with none of the bored-well problems.

Most problems exist in the trailer park and bored wells appear the most vulnerable in this area.

b. Water quantity. This area, in general, has low-yield wells that are the only source of drinking water. The maximum reported yield is 50 gpm, and the number of "dry holes" is large. Of 54 wells inventoried 19 (35 percent) are dry. Thirteen of the dry holes (65 percent of all dry holes) are in the trailer park.

c. Water quality. According to several people at the trailer park, their drinking water is characterized by high mineral content. They have complained of water staining clothes, a strong iron taste, and muddy water. These problems, they say, become extreme after blasts and are especially critical during summer months.

Seven (19 percent) of the 37 wells in use had or have water quality problems. One is bored and 6 are drilled wells. Five of the drilled wells have filters and have resolved the problem. Therefore, there remain 2 wells with water quality problems.

d. Fluctuation of water level after blasting. Residents of the area have complained that blasting is affecting the water level in their wells. They have said that after a blast the water level declines rather rapidly, then comes back to normal level after 2 or 3 days. Some residents have also complained that after a very strong blast the water level in their wells dropped and never came back. Two examples of this situation are:

> In 1980 the well of the Antioch Baptist Church went dry overnight after a blast. The well had to be drilled an additional 100 feet before water was found.
>
> Mr. and Mrs. James P. Martin, who live at the south end of the trailer park, have complained of sudden drops in their well water level after blasting. They reported several pumps burning out because of the water level dropping below the pump intake.

e. Vibration of ground after blasting. One of the most common complaints among the residents is ground vibration after blasting. A large number of residents have repeatedly commented on this problem. Mrs. Vera Hardin, whose house is located approximately 4,500 ft southeast of the quarry, reported cracks in the walls of her house due to blasts. Another example was given by Mrs. Joan Davis who had a window broken in her trailer, believed to be caused by air blast.

STUDY OF THE HYDROLOGIC PROBLEMS

Water Quantity

Analyses of well data show that this area is characterized by wells with low yields and that water quantity problems may have worsened due to one or more of the following reasons:

1. Climatic conditions.
2. Lowering of water table.
3. Dewatering of fractures.
4. Reduction of recharge areas.
5. Modification of drainage.

Climatic conditions. Dry weather adversely affects ground-water supply. Ground water in the Piedmont is replenished by rainfall, and in times of drought the water table can be lowered critically. High temperatures cause higher rates of evapotranspiration that also can reduce water levels. Moreover, increased demand for water during hot and dry weather can cause even more strain on already low ground water supplies.

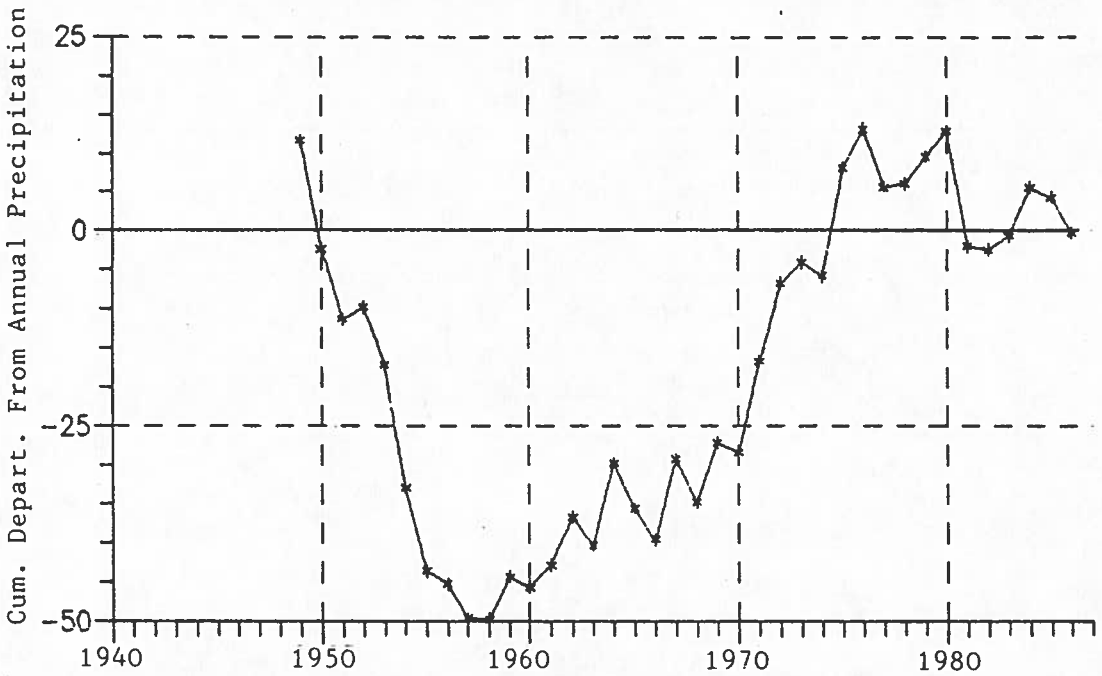
Figures 6-A and 6-B show the cumulative departure from normal precipitation for the Gaston Shoals gage, the closest precipitation gage to the study area, 8-1/2 miles to the west. The beginning of the curve shows a significant plunge as the result of the drought of the 1950's. Over the next 20 years a significant rise occurs. The 1980's are generally declining again.

It is not known if this is a typical rainfall pattern upon which future trenads can be based or if the wet and dry periods during the past 38 years are extreme in nature.

A few observations can be made. It appears that the more recent trend, Figures 6-A and 6-B, shows that currently precipitation seems to be lower than normal following a short wet period (1983-84). If this continues, there will be less precipitation available for recharge and the water table will stabilize at a lower level.

The water table is also affected by short-term fluctuations, the most important of which is the seasonal variation. Figure 6-B is a plot of precipitation for the Gaston Shoals station for the past 8 years. Monthly values of precipitation are plotted as cumulative departures from normal. Intensity and duration of rainfall are closely related to ground-water recharge. Whereas precipitation of low intensity and long duration is favorable for ground-water recharge, precipitation of high intensity and short duration is not, as it tends to run off rather than infiltrate.

Figure 6-B shows that during 1985 there were 4 months with above-normal precipitation and 8 with below-normal precipitation. This suggests that ground-water recharge was less than normal for most of the year. Moreover, since 2 of the 4 above-normal months (August and November) had high-intensitity precipitation it is very likely that most of the rain ran off and did not infiltrate the ground to recharge the water table. This indicates that before the drought of 1986 there was already a deficiency in ground-water recharge.



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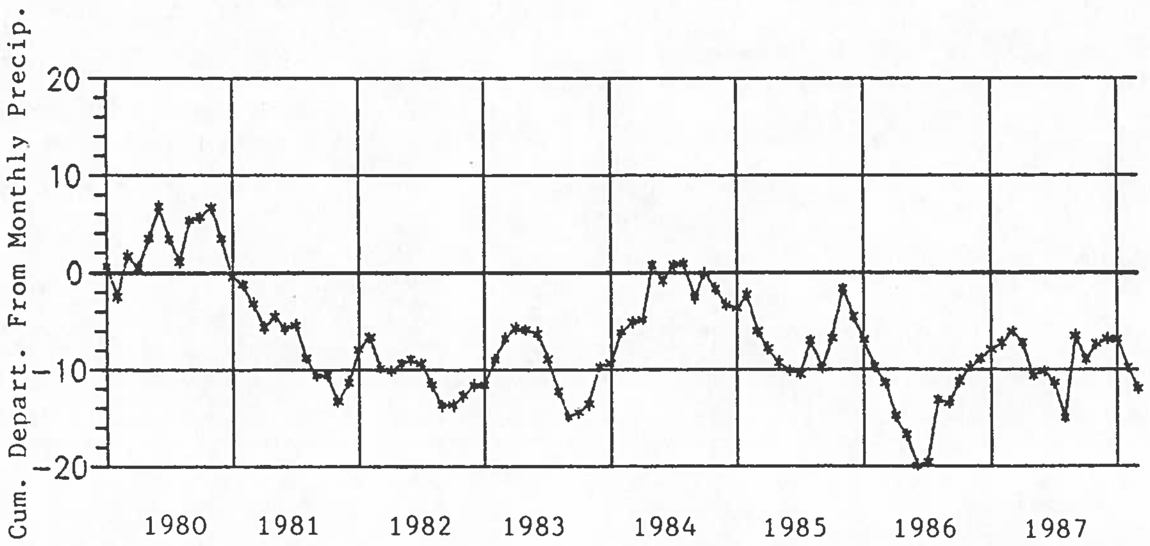


B

Figure 6. Cumulative departure from normal precipitation, in inches, Gaston Shoals, S.C.

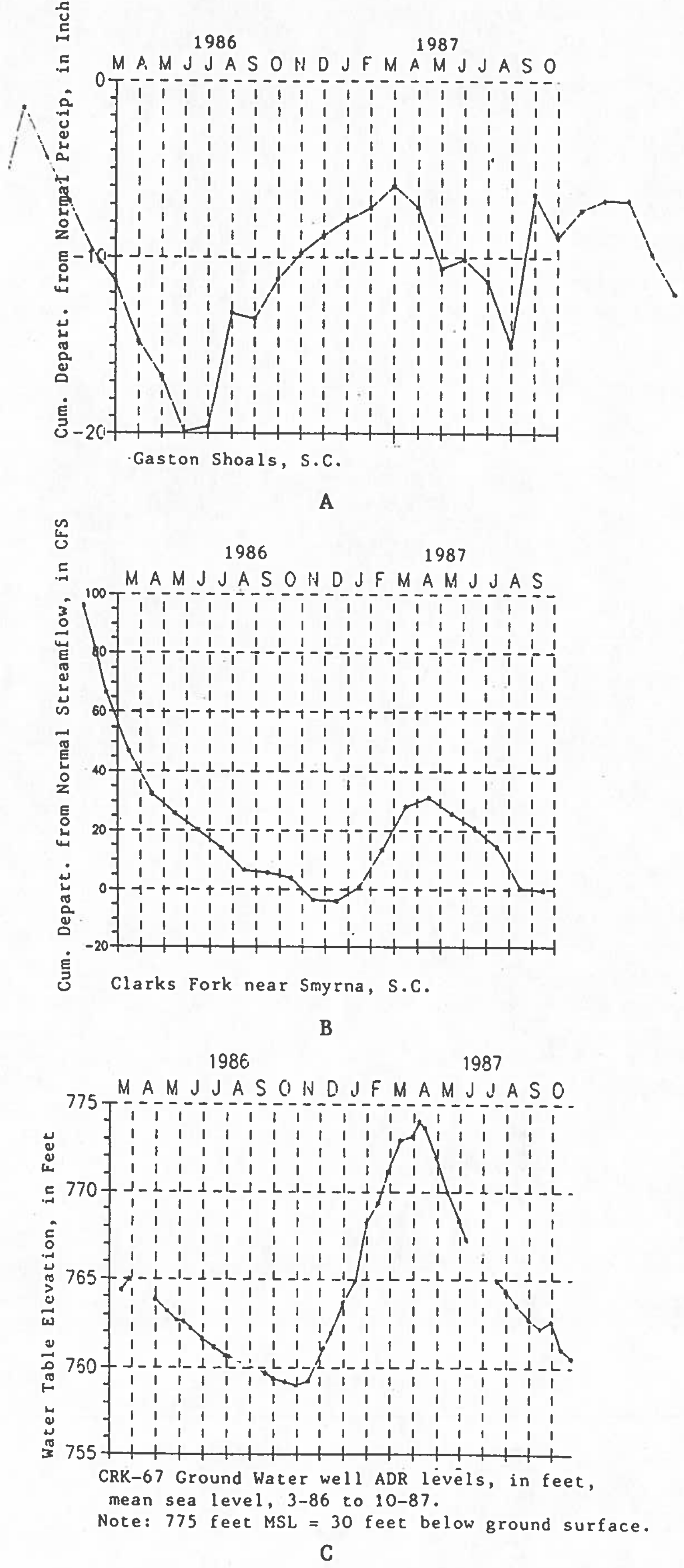


Figure 7. Cumulative departure from normal precipitation (A) and streamflow (B) compared with water-table elevation (C) for the period March 1986 through September 1987.

One method of evaluating the impacts of precipitation variation on the local water resources is to see how local streamflow and ground water levels fluctuate. The cumulative departure from normal streamflow for Clarks Fork Creek (Figure 7-B), the drainage basin immediately east of Mill Creek and the water levels (Figure 7-C) from well CRK-67 just south of the residential area are compared with precipitation (Figure 7-A) over the study period. Streamflow shows very close correlation with precipitation and fairly close correlation with the water table fluctuations.

Because shallow wells depend on the water table, they should be deep enough to accommodate long- and short-term fluctuations. The local ground water level fluctuations must be evaluated in order to assess the susceptibility of wells to droughts. Ideally the wells should be constructed so that the intakes are not only lower than the low-water elevation but deep enough to allow pumping during those times without exposing the pump.

From March 1986 to November 1986 the water table in the trailer park area declined 7 feet. This was followed by a rise of 15 feet by April 1987. Since April 1987 the water table has dropped almost 14 feet (Figure 7-C). Since the recording of water levels in this well took place during the peak of the 1985-86 drought it may indicate the lowest water levels to be expected. If the magnitude of the ground water fluctuation is similar to that of streamflow (Figure 7-B) or precipitation (Figure 7-A), it could be inferred that the ground water levels were higher in 1984, just as the streamflow and the precipitation. Similarily, it could be inferred that the ground water levels could go much lower in response to a drought similar to the one from 1949 to 1956 (Figure 6-A).

<u>Lowering of the water table</u>. The 90-foot deep pit constructed in the lower portion of the northern basin acted to lower the local water table. The pit acts as a huge well, allowing ground water to flow into it. The quarry operation pumps this water out. The water table has been effectively lowered to the base of the pit. Figure 8 shows close-up projections of the study area and the water table. In Figure 8 (C and D) three-dimensional computer-generated representations of the water table before and after the start of the quarry operations are depicted. It is evident from these plots that the pit works as a sink, controlling the gradient and direction of the local ground water flow. The pit is continuously collecting ground water and has increased the natural gradient of the water table.

The pit's radius of influence is the radial distance to where effects of the sink are negligible. Because there are no data regarding aquifer characteristics, it is not possible to estimate the radius of influence nor to quantify the impact of the pit on wells in the trailer park.

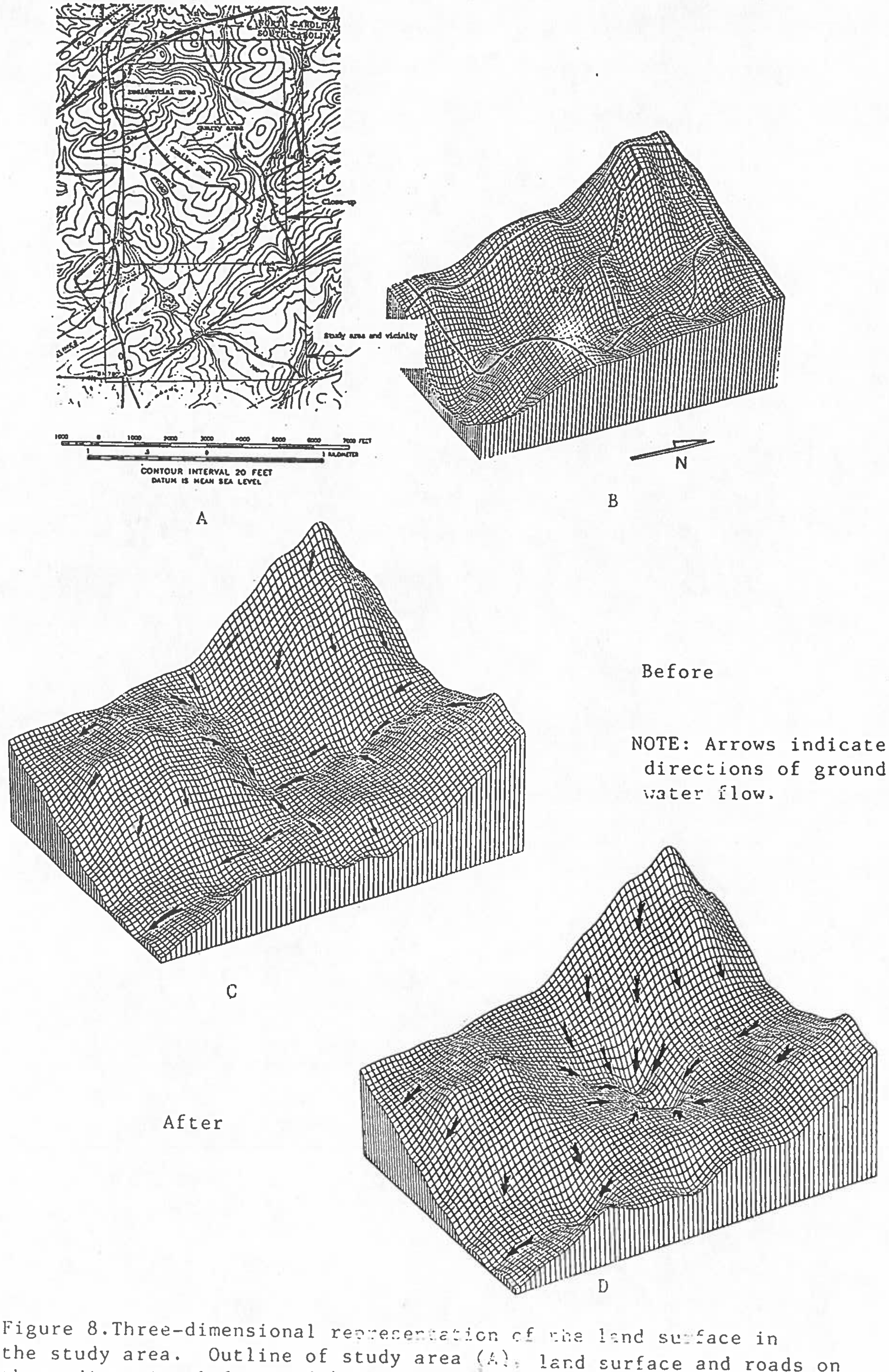


Figure 8.Three-dimensional representation of the land surface in the study area. Outline of study area (A), land surface and roads on three-dimensional figure (B), and representations of water table before (C) and after (D) quarry construction.

Dewatering of fractures. In the Piedmont Region bedrock wells are supplied with water from the saprolite through a system of fractures. The saprolite serves as storage, and the fractures provide the network through which water must flow. Many fractures are intensively interconnected whereas others may be only slightly interconnected. The amount of water available to a deep well is dependent on the discharge from and number of fractures intersected, their orientation, and the size of the recharge area.

If the water table is lowered abnormally or the recharge area of a well is disturbed, the well yield will be adversely affected. Wells supplied by only one fracture or a few fractures would be more subject to problems than wells in an extensive fracture network.

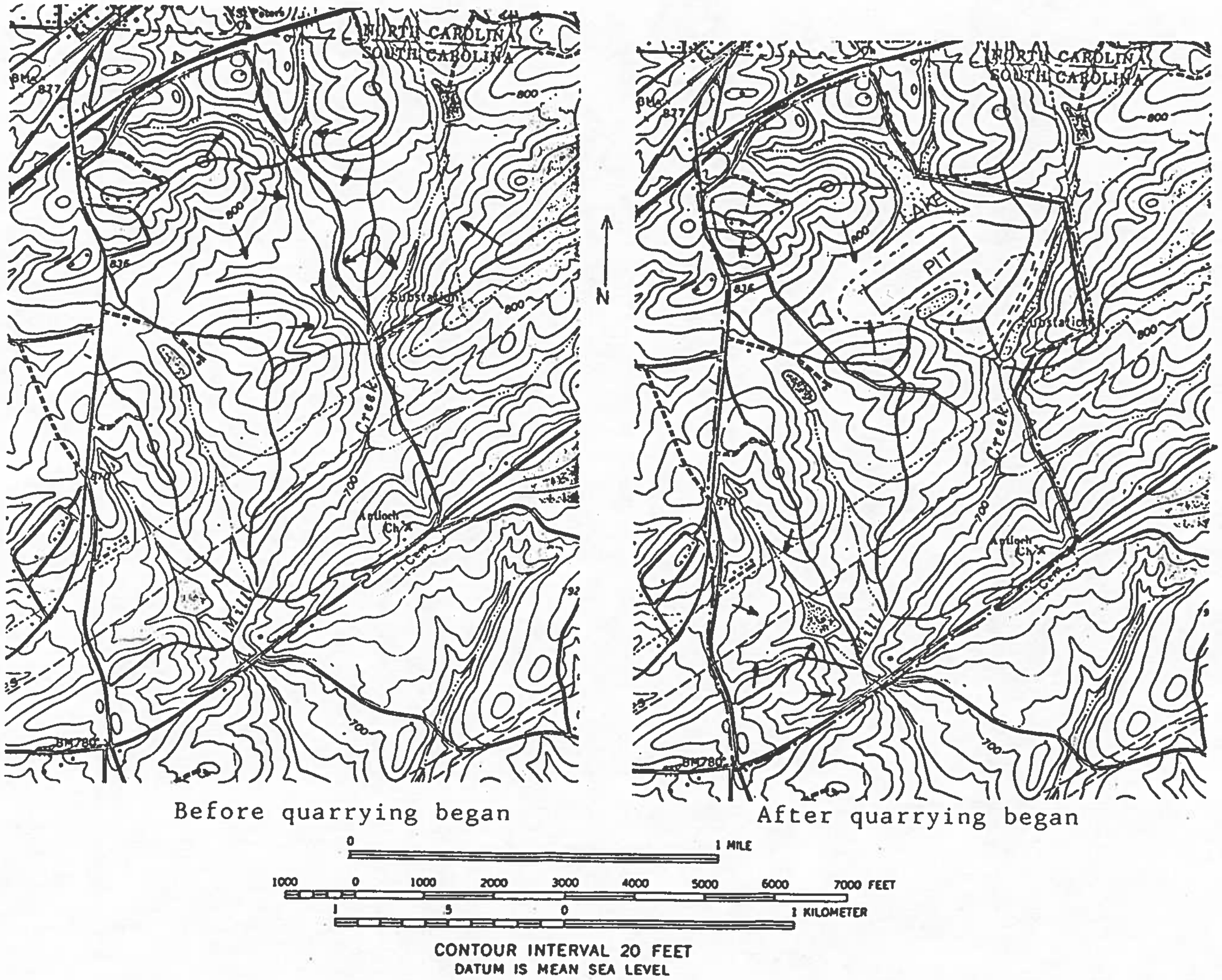
To understand the effects that the pit has had on deep wells, it is necessary to have information not only about recharge areas but also about the fracture system. As there is presently no information on the fracture system, a fracture-trace analysis of the area is needed.

Reduction of recharge areas. Figure 9 shows two topographic maps of the study area. The figures, left to right, represent conditions before and after the quarrying operations began. Thick lines show the drainage basins, and arrows indicate the direction of surface runoff. If it is assumed that surface and ground water divides coincide, the arrows would also show the direction of local ground-water flow.

Assuming that local ground water is recharged by local precipitation, the volume of water infiltrating the ground is estimated by multiplying the surface area by the percentage of rainfall that infiltrates the ground. If this percentage remains constant, the volume of water infiltrating the ground is proportional to the surface area. Therefore reduction of infiltration rate of some of the areas will result in reduction of ground-water recharge.

The pit, being of considerable areal extent and depth (400 by 1,500 by 90 feet representing 9 1/2 percent of quarry area, or 1 3/4 percent of study area) has modified surface and ground water flow. The pit is collecting all direct rainfall and nearby surface runoff. This water is pumped out of the pit and little is left for infiltration. Outside the pit, construction changes have also resulted in reduction of infiltration rates. Roads, buildings, parking lots, and settling ponds cover extensive areas, thus reducing infiltration. Thus, roughly 2 percent of the study area's recharge has been eliminated and portions of another 21 percent (quarry property is 23 percent of area) has had its infiltration rate reduced. Most of this area is within the lower and eastern portions of the northern ground-water basin. Recharge impacts should therefore be limited to this area.

To compensate for the reduction of recharge, the quarry should induce ground-water recharge at selected sites. These sites should be chosen where infiltration properties of the soil are most favorable and where artificial recharge would not interfere with quarrying processes.



Before quarrying began

After quarrying began

Figure 9. Major and minor drainage basins and direction of surface runoff.

Drainage modification. Construction of lakes, ponds, and diversion channels and removal of vegetation has resulted in an increase in the runoff rate. Presently, there is more surface water intercepted and routed out of the quarry site and less water left for infiltration to recharge the water table. The lake and the ponds are collecting runoff and subsurface flow and returning it to the channels to be discharged into Mill Creek as surface water. It is important to note that during the summer of 1986 the lake and ponds showed an insignificant water level decline while nearby creeks were dry and the water table had a 5-foot decline. This indicates that these surface-water bodies are not contributing significantly to the ground water.

Removal of vegetation is another of the causes for reduction of ground-water recharge. Without vegetative cover water runs faster over the ground and has less chance for infiltration.

Water Quality

Four wells were sampled and complete chemical analyses made. Reports are presented in Appendix A. The analyses show that the water is soft, has low total dissolved solids, and has a pH between 6.5 and 7.5. The water is a calcium bicarbonate type.

Only one of the sampled wells showed a high iron content. It had a total iron concentration equal to 836 ug/L (micrograms per liter), or 0.84 mg/L (milligrams per liter). The standards of the U.S. Environmental Protection Agency recommend that iron content not exceed 0.3 mg/L. Although 0.84 mg/L is almost three times as large as the recommended maximum, it is not uncommon for ground water from rocks of the Kings Mountain belt. The iron, in some cases, can be removed by filtration, especially if it is not dissolved.

Even though these analyses do not show serious water quality problems, some residents have reported continuous problems, while others have reported problems only after blasts or rainfall. These water quality problems may have resulted from poor well construction. Most wells in the area were drilled before stringent regulations[1] went into effect, and they do not follow design standards for wells of type I and V (open hole, and bored or dug).

In some situations little attention was paid to protecting the well against surface contamination. Many wells were not grouted, cement pads were not constructed around the wells, and some casings were not set properly into the bedrock. Most of the abandoned wells are open and represent a nuisance and point of possible contamination. This and the fact that problems arise after rainfall or blasts suggest that water quality problems are related to poor well construction, which allows unconsolidated saprolite or other material to slough out from around the well casing and down into the well.

Fluctuation of Water Level after Blasts

Since March 1986 an automatic data recorder (ADR) has been continuously recording water levels in the vicinity of the Vulcan Materials quarry (Figure 10). Initially two ADR's were employed but one malfunctioned and was removed. Data was plotted to disclose predominant trends and cycles. Along with these water levels, blasting times were also marked to study the impact of blasting on local water level changes.

[1] SCDHEC R.61-71: Well Standards and Regulations, 6/28/85.

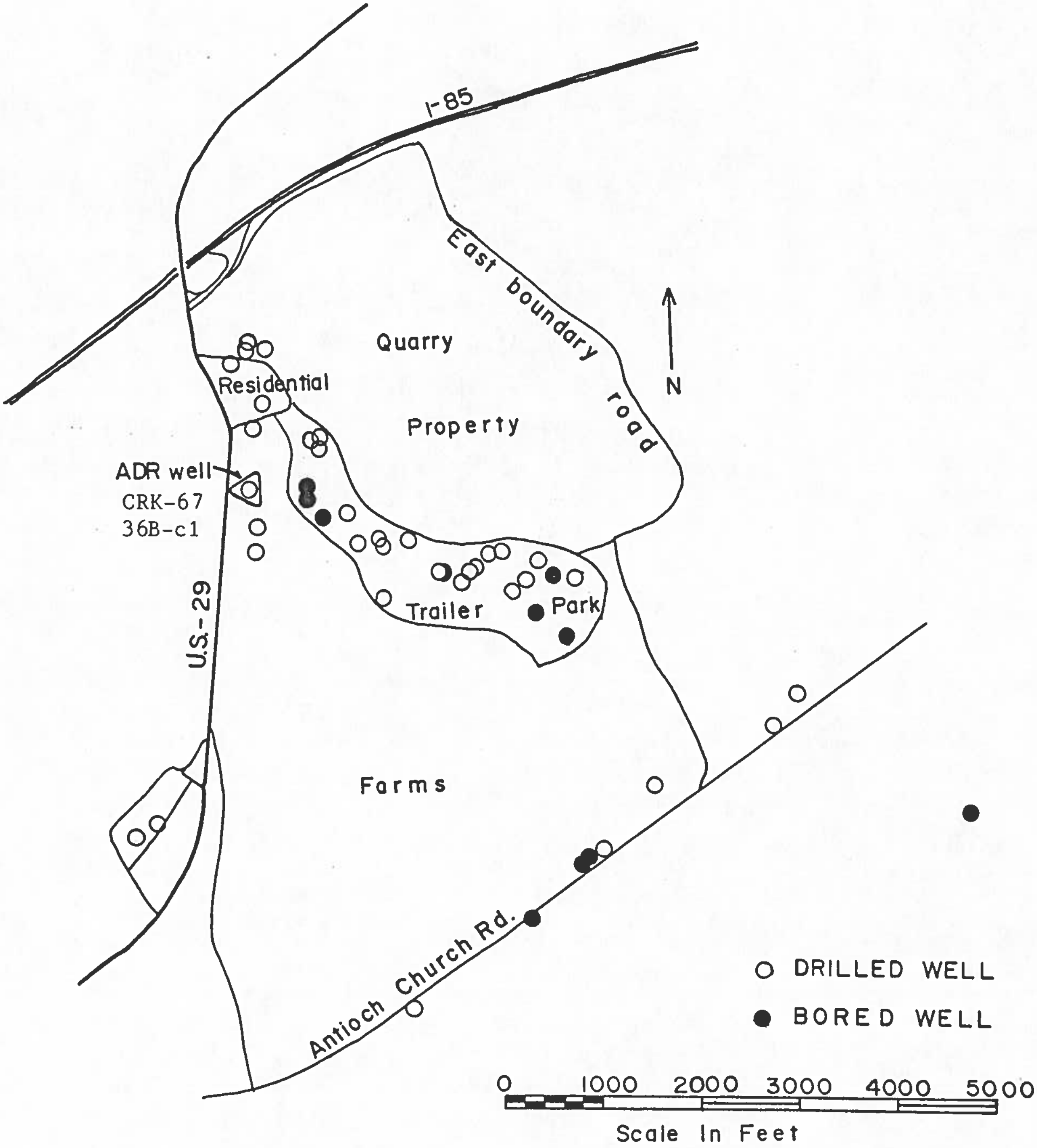


Figure 10. Location of ground water Automatic Data Recorder (ADR) well.

The well chosen for this study is located a half-mile west of the center of the quarry pit and is a 6-inch well that is 405 feet deep with 66 feet of galvanized casing (well # CRK-67/36B-cl). The ADR was installed March 12, 1986, and records the water level every 6 minutes.

The data were read manually from the ADR tape and from March to November 1986 indicated a decline of more than 6 feet in water level. Figure 11 shows a representative 3-month period (May to July). The horizontal axis of this figure is time and has been divided into days. Every 7 days a larger tick represents a week. The vertical axis is elevation, in feet, with respect to mean sea level. Inspection of the graph shows that:

1. There has been more than a 3-foot decline in elevation of the water table over a 3-month period. The first measurement on May 1, 1986, was 763.84, and the last on July 30, 1986, was 760.69.

2. The gap between May 28 and June 6 indicates loss of data, due to a dead battery in the recorder.

3. The ground water shows a gradually declining trend. A daily cycle of rise and fall is evident, and daily changes may be as much as 0.1 foot. There may have been a slight rise and then decline again during the time of lost data, as indicated by the shift to the right of the line's slope.

Quarry blasts are plotted on the hydrograph. During this 3-month period, there were 17 blasts reported by the quarry. Dates and times of blasts are listed below:

DATE	TIME
5/01/86	11:44 a.m.
5/06/86 (two blasts)	8:56 a.m.
5/12/86 (two blasts)	10:03 a.m.
5/28/86	11:05 a.m.
5/29/86	9:56 a.m.
6/05/86	10:10 a.m.
6/10/86	10:23 a.m.
6/20/86	1:54 p.m.
6/24/86	9:45 a.m.
7/08/86	11:05 a.m.
7/11/86	8:50 a.m.
7/17/86	8:44 a.m.
7/23/86	10:28 a.m.
7/25/86	11:21 a.m.
7/31/86	9:08 a.m.

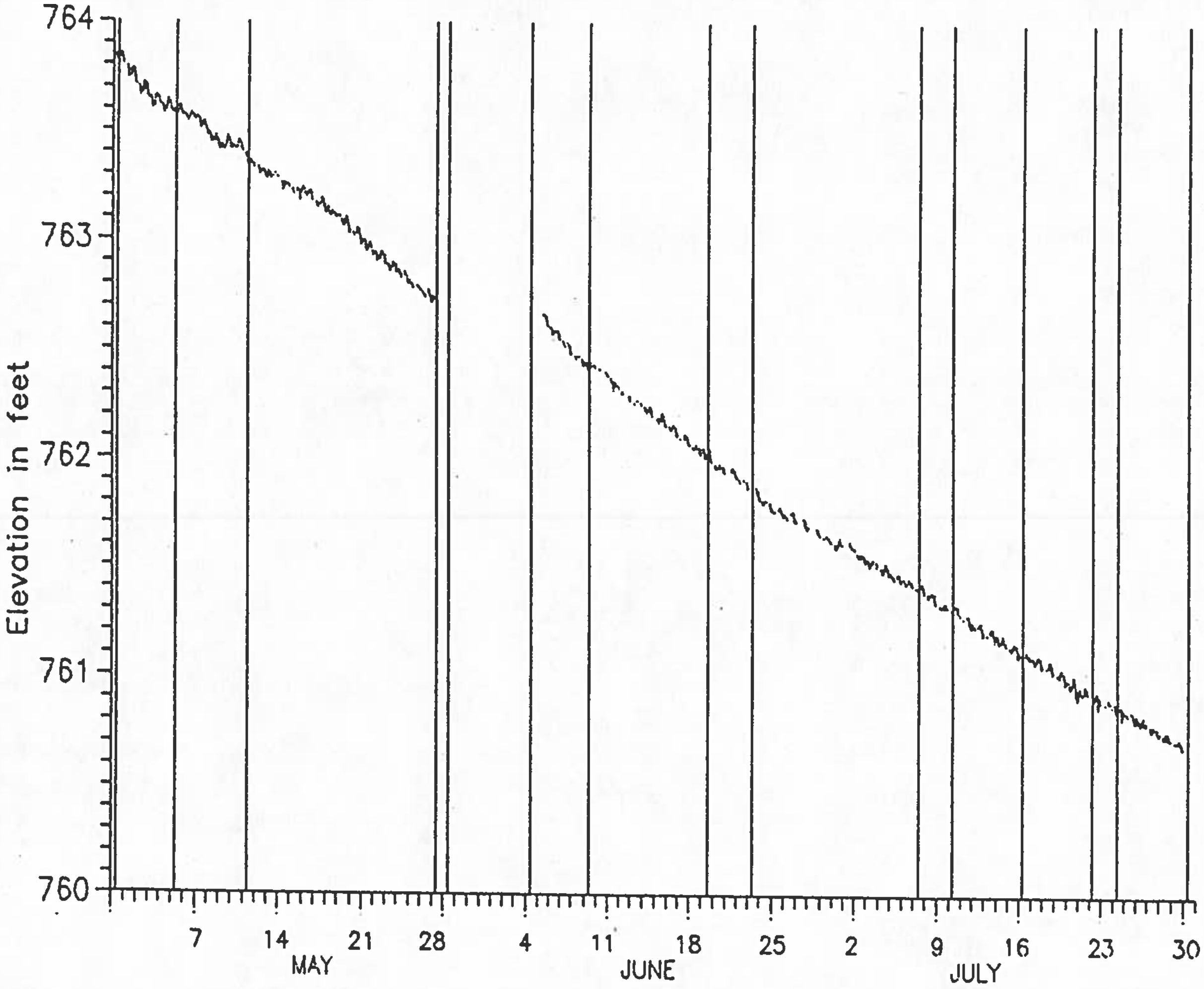


Figure 11. Water levels of observation well, May to July 1986. Vertical lines indicate times of blasts.

No noticeable fluctuation in the water level is visible after blasts. Daily trends are uninterrupted and show no response to the blasts. This could be viewed in three different ways:

a. Blasting is not affecting ground-water levels in the area surrounding the mine.

b. The well selected to be monitored does not reflect the general situation of the area.

c. The amount of explosives and location of blasts during this period were such that they did not interfere with water level at the observation well.

Insufficient evidence exists to support one or more of these explanations. Directed future studies are needed to provide the necessary information.

CONCLUSIONS

1. Of the 54 wells inventoried, 26 (48 percent) had water quantity problems. Seven of these were bored and 19 were drilled wells. Two of these had their problems solved by redrilling to greater depths. Nineteen (5 bored, 14 drilled) were dry or unusable. The remainder were still usable but of variable dependability. The trailer park had the highest percentage of quantity problems, at 52 percent (16 out of 31), followed by the residential area at 50 percent (4 out of 8) and the farm area at 40 percent (6 out of 15). Drilled wells accounted for 69 percent of the quantity problems in the trailer park, 83 percent of the quantity problems in the farm area, and 75 percent of the problems in the residential area.

2. Nine of the inventoried wells had water quality problems (1 bored, 8 drilled) and 4 of these (all drilled) were solved by installing filters. The trailer park had the most water quality problems, with 7 out of 31 (23 percent), followed by the residential area with 1 out of 8 (12.5 percent) and the farm area with 1 out of 15 (7 percent). Drilled wells accounted for 87 percent of the water quality problems in the trailer park, and 100 percent of the quality problems in the farm area and residential area (represented by one well each).

3. It is important to note that while drilled wells represent a large proportion of the problems, both quantity and quality, in the area, there are too few bored wells in the survey to make a fair representation, and an analysis should be done on success of a well based on its topographic location. Many of the bored wells are located more favorably than the drilled wells in draws and valleys, while many of the drilled wells are unsuitably located on ridges and hilltops.

4. Wells with water quality problems may have their problems resolved by using water filters to reduce the concentration of iron and to lessen the turbidity. In some instances better construction procedures for new wells would eliminate the turbidity and reduce the risk of surface contamination. A cement pad and grouting of the well will prevent seepage of surface water.

5. There are seven bored wells with water quantity problems, two of which are still in use. It is likely that they are not deep enough to accommodate fluctuations of the water table. The water table, during dry periods, may drop below the bottom of the saprolite and into the bedrock. Bored wells, then, would not yield water and would remain dry for as long as there is a dry spell.

6. The one well with water quantity problems still being used in the trailer park was drilled in March 1981, is 265 feet deep, and has 75 feet of 6-inch casing. At the time of drilling, the well yielded 3 gallons per minute and, according to the owners, since 1985 it has decreased in yield. The well is located about 1,500 feet southeast of the quarry pit, and its direction coincides with the strike of one of the major fracture sets in the area. It is possible that water-bearing fractures that were supplying the well are now dry because of the reduction of ground-water recharge and/or because the pit is draining the fractures.

7. In general, the water quality and quantity problems observed in this investigation are related to one or more of the following:

a. Hydraulic properties of the aquifers. There are two types of aquifer in the area of study. The shallow, low-yielding saprolite aquifer is largely affected by climatic conditions and is susceptible to surface contamination. The other aquifer is the fractured crystalline rock. This aquifer, in general, has good water quality and quantity properties; however, the fractures are hard to locate and identify. Drilled wells seem to have a 50-percent chance of success. In complex geologic environments like the one addressed in this report, the chance of obtaining large-yield wells is even smaller.

b. Limited space for well location. Deep wells must intercept water-bearing fractures to yield significant amounts of water. The density and distribution of the fractures are irregular and of limited extent. The best place to drill a well is one with the highest density of fractures. Not all homesites are ideal for drilling wells, nor are they always near ideal areas for drilling deep wells. This is a very limiting constraint and is particularly true in the trailer park where lots are small and the possibility of finding a good well site on each parcel is consequently lessened.

c. Modification of drainage basin. Topographic changes and hydrologic modifications of the basin introduced by the quarry in the study area has resulted in the reduction of ground-water recharge.

d. Lowering of the water table. The excavation of a 1,500- by 400- by 90-foot pit has caused the development of a large cone of depression. The radius of influence of this cone is unknown because data are not available regarding aquifer parameters. Nevertheless, the water table must readjust to the new conditions that will lower the local water table a decreasing amount with distance from the pit. This will lower water levels in wells, thus requiring greater water lifts and lower yields. The water-table lowering may be enough to expose a well pump after short pumping periods.

8. Vibration of structures due to blasting is the most common complaint among residents of the area.

9. Blasting did not affect the water level in the observation well monitored by the Water Resources Commission in the study area.

10. Long- and short-term fluctuations of the water table have a direct impact on the availability of ground water. Fluctuations of the water table of 10 feet or more have been reported as characteristic of the Piedmont Region.

11. The water level in the observation well (CRK-67/36B-c1) declined by more than 4 feet from March to July, 1986, and another 2 feet by mid-November. This ground-water level decline has been associated with the lack of precipitation and excessive heat during the drought of 1986. The precipitation for 1985 and 1986 was below normal, suggesting that ground-water recharge for those two years may have been below normal. This recharge shortage affected shallow wells more than deep wells.

12. The chemical analyses indicated that there are ground-water quality problems, but they are common to a few wells and are not widespread.

RECOMMENDATIONS

1. Wells should be constructed according to the Well Standards and Regulations (South Carolina Department of Health and Environmental Control R.61-71), and special care should be given to grouting and casing placement into the bedrock. Shallow wells should have, although not required by law, a cement pad around the well to avoid surface water infiltration. This would prevent surface contamination and thereby improve water quality. Deep wells also should have a cement pad, and casing should be properly secured into the bedrock. This not only would prevent surface water contamination but also the caving of the upper part of the well.

2. From the currently used wells identified as having problems, 2 should have their construction improved and use filters to control the water quality problem. The other 2 bored wells may improve their yield as the water table rises. Nevertheless, they will always be subject to seasonal variations. Of the 2 wells with water quantity problems, 1 had a yield of only 1 gpm and the other 3 gpm. This last well has been reported to have decreased in yield continuously in the past few years. The owners suspect that changes in the well yield occurred because of the quarry; however, evidence so far does not indicate a direct connection between the reduction of yield and the quarrying.

   If the yield of this well continues to decrease, the well eventually will go dry. A new well is recommended. Before site selection, analysis of fracture traces, drainage patterns, and recharge and discharge are suggested.

3. Water filters should be used to reduce the problems with iron concentration and sediment.

4. Wells should be reconditioned periodically. Pumps should be pulled out and cleaned every 3 or 4 years or as needed. Wells should be flushed to remove sediments from the bottom and walls of well and pipes once a year.

5. New wells should be developed sufficiently to increase yields and improve water quality.

6. Before well-site selection, technical assistance is advised. The South Carolina Water Resources Commission has regional offices in the state that could be consulted. The Greenville Office is responsible for the counties in the Piedmont Region.

7. Shallow wells should be bored deep enough to accommodate seasonal and other fluctuations of the water table.

8. The quarry should minimize the impact of the pit on the water table. Appropriate means of recharge should be devised to control the decline of the water table without hindering the quarrying process.

9. The quarry should be required to maintain flow meters on all their pumps and to periodically report volumes of water pumped and used.

10. The quarry should restore the vegetative cover to reduce surface runoff and increase infiltration. This cover would also serve as a noise barrier.

11. Additional studies such as fracture-trace analysis, infiltration tests, and pumping tests are needed to understand the hydrodymamics of the system and to quantify the hydrological impact of the Vulcan Marble Quarry operations on the surrounding area.

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APPENDIX A - WATER QUALITY ANALYSES

South Carolina Water Resources Commission
Water Quality Laboratory Report

SCWRC No.: 36B-b016 County: Cherokee Lab No.: 86-110-003
Field No.: CRK-74 Latitude: 350918 Longitude: 812634
Owner s Name: Paul Clayton Address: Rt. 3
City: Blacksburg State: SC Zip: 29702
Date Collected: 04/09/86 Time Collected: 1245 Collected by: HLM/DTC
Project: Vulcan Project No.: 2004 Water Use: DO
Water Type: GW Requested By: Mitchell Office: 06
Aquifer Code: km Analysis Code Requested: 1000
Field Remarks: Kitchen tap

FIELD MEASUREMENTS

Parameter	Value	Units	Parameter	Value	Units
Depth	0	Feet	Conductivity	55	umho/cm2
pH, Field	6.9	SU	Temp. Field	15.4	C
DO, Field	0.00	mg/L	Alk., Field	29.2	mg/L

LABORATORY RESULTS

Parameter	Concentration	Units	Parameter	Concentration	Units
Acidity	0.0	mg/L	Calcium, Tot.	4.8	mg/L
Alkalinity	24.4	mg/L	Calcium, Dis.	4.7	mg/L
Chloride	1.7	mg/L	Iron, Tot.	836	ug/L
Spec. Cond.	68	umho/cm2	Iron, Dis.	7	ug/L
Fluoride	0.15	mg/L	Magnesium, Tot.	2.45	mg/L
Hard. Calc.	21	mg/L	Magnesium, Dis.	2.44	mg/L
Nitrate	0.0	mg/L	Manganese, Tot.	27	ug/L
pH, Lab.	6.75	SU	Manganese, Dis.	23	ug/L
Phos., Ortho.	0.36	mg/L	Potassium, Tot.	1.50	mg/L
Tot. Dis. Sol.	52	mg/L	Potassium, Dis.	1.40	mg/L
Sulfate	4.0	mg/L	Silica, Dis.	16.25	mg/L
			Silicon, Dis.	7.60	mg/L
			Sodium, Tot.	2.4	mg/L
			Sodium, Dis.	2.2	mg/L

Laboratory Remarks:

OFFICAL USE ONLY: This laboratory analysis cannot be used to satisfy any private contractual obligations.
This analysis should not be construed to mean that this water is potable, for that determination consult the S.C. Department of Health and Environmental Control.

Date Completed: 07/14/86
Date Released: 07/14/86

By: Lawrence H. Logan
Chief Chemist

S.C.D.H.E.C. Laboratory Id. No. 40999
Issued: December 5, 1983

S.C.D.H.E.C. Certification No. [illegible]
Expires: December 5, 1986

S. C. WRC Lab Report Version 03-86

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                        QUALITY CONTROL REPORT
r SCWRC Number : 36B-b016
boratory Sample No.: 86-110-003       Water Quality Record Number :       3

******* Water Quality Parameters Exceeding Drinking Water Standards ********

e total iron concentration exceeds the 300 ug/L limit.

****************************** IONIC BALANCE *********************************

                             CATIONS

ssolved Calcium =      4.7        Millequivalents Calcium    =     0.23453
ssolved Iron    =      7          Millequivalents Iron    =   0.00037604
ssolved Magnesium =     2.44      Millequivalents Magnesium  =    0.2007144
ssolved Manganese =     23        Millequivalents Manganese =   0.0008372
ssolved Potassium =      1.40     Millequivalents Potassium     =    0.0357980
ssolved Sodium   =     2.2        Millequivalents Sodium   =      0.09570

otal Cation Millequivalents =   0.56795564

                             ANIONS

lkalinity    =    24.4            Millequivalents Alkalinity  =    0.399916
hloride      =     1.7            Millequivalents Chloride  =    0.047957
luoride      =  0.15              Millequivalents Fluoride  =   0.0078960
itrate       =  0.0               Millequivalents Nitrate  =     0.000000
otal Phosphorus =   0.36          Millequivalents Tot. Phos  =   0.0113724
ulfate =     4.0                  Millequivalents Sulfate   =    0.083280

otal Anion Millequivalents =   0.5504214
-----------------------------------------------------------------------------
otal Millequivalents =     1.11837704
ifference (Cations - Anions) =    0.01753424

% IONIC BALANCE    =    1.56782903
-----------------------------------------------------------------------------


****** Description of the Precision of this Water Quality Analysis ******
is analysis is a Class I A analysis.
 Class I A analysis is defined as an analysis in which all major ions
ave been determined and the results are with USGS Ionic Balance Control
imits and the Parameter Quality Control Limits.




**************************** WARNING MESSAGES ****************************

RNING: Cation to conductivity ratio is less than 0.92.
       This ratio is    0.83522888 .
RNING: Anion to conductivity ratio is less than 0.92.
       This ratio is    0.8094432 .
```

South Carolina Water Resources Commission
Water Quality Laboratory Report

SCWRC No.: 36B-b020
Field No.: CRK-78
Owner s Name: Carolyn Camp
City: Grover
Date Collected: 04/15/86
Project: Vulcan
Water Type: GW
Aquifer Code: km
County: Cherokee
Latitude: 350924
Lab No.: 86-110-004
Longitude: 812653
Address: P.O. Box 141
State: NC
Zip: 28073
Time Collected: 1200
Collected by: HLM/DTC
Project No.: 2004
Water Use: DO
Requested By: Mitchell
Office: 06
Analysis Code Requested: 1000
Field Remarks: Tap at front of house next to friendly alaskan malamute

FIELD MEASUREMENTS

Parameter	Value	Units	Parameter	Value	Units
Depth	0	Feet	Conductivity	40	umho/cm2
pH, Field	6.6	SU	Temp. Field	16.5	C
DO, Field	0.00	mg/L	Alk., Field	21.7	mg/L

LABORATORY RESULTS

Parameter	Concentration	Units	Parameter	Concentration	Units
Acidity	0.0	mg/L	Calcium, Tot.	5.2	mg/L
Alkalinity	29.2	mg/L	Calcium, Dis.	5.1	mg/L
Chloride	1.2	mg/L	Iron, Tot.	20	ug/L
Spec. Cond.	48	umho/cm2	Iron, Dis.	0	ug/L
Fluoride	0.00	mg/L	Magnesium, Tot.	2.51	mg/L
Hard. Calc.	23	mg/L	Magnesium, Dis.	2.50	mg/L
Nitrate	0.6	mg/L	Manganese, Tot.	1	ug/L
pH, Lab.	6.45	SU	Manganese, Dis.	1	ug/L
Phos., Ortho.	0.00	mg/L	Potassium, Tot.	0.70	mg/L
Tot. Dis. Sol.	24	mg/L	Potassium, Dis.	0.60	mg/L
Sulfate	0.0	mg/L	Silica, Dis.	14.97	mg/L
			Silicon, Dis.	7.00	mg/L
			Sodium, Tot.	1.4	mg/L
			Sodium, Dis.	1.2	mg/L

aboratory Remarks:

OFFICAL USE ONLY: This laboratory analysis cannot be used to satisfy any private contractual obligations.
This analysis should not be construed to mean that this water is potable , for that determination consult the S.C. Department of Health and Environmental Control.

Date Completed: 07/14/86
Date Released: 07/14/86

By: Laurence H. Lazar
Chief Chemist

S.C.D.H.E.C. Laboratory Id. No. 40999
Issued: December 5, 1983

S.C.D.H.E.C. Certification No. 83001
Expires: December 5, 1986

S. C. WRC Lab Report Version 03-86

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                         QUALITY CONTROL REPORT
For SCWRC Number : 36B-b020
Laboratory Sample No.: 86-110-004      Water Quality Record Number :      4

********* Water Quality Parameters Exceeding Drinking Water Standarus ********

All parameters are below the drinking water limit.

****************************** IONIC BALANCE ******************************

                              CATIONS

issolved Calcium =      5.1      Millequivalents Calcium   =      0.25449
issolved Iron   =       0        Millequivalents Iron   =   0.00000000
issolved Magnesium =     2.50    Millequivalents Magnesium  =   0.2056500
issolved Manganese =      1      Millequivalents Manganese =   0.0000364
issolved Potassium =     0.60    Millequivalents Potassium    =   0.0153420
issolved Sodium   =     1.2      Millequivalents Sodium   =     0.05220

  Total Cation Millequivalents =    0.52771840

                              ANIONS

 Alkalinity   =     29.2         Millequivalents Alkalinity  =    0.478588
 Chloride     =      1.2         Millequivalents Chloride   =   0.033852
 Fluoride     =    0.00          Millequivalents Fluoride   =   0.0000000
 Nitrate      =    0.60          Millequivalents Nitrate   =    0.009678
 Total Phosphorus =    0.00      Millequivalents Tot. Phos   =   0.0000000
 Sulfate =       0.0             Millequivalents Sulfate    =    0.000000

 Total Anion Millequivalents =   0.5221180
------------------------------------------------------------------------------
 Total Millequivalents =   1.04983640
 Difference (Cations - Anions) =   0.00560040

 % IONIC BALANCE    =   0.53345454
------------------------------------------------------------------------------

********* Description of the Precision of this Water Quality Analysis ******
This analysis is a Class I A analysis.
 A Class I A analysis is defined as an analysis in which all major ions
 have been determined and the results are with USGS Ionic Balance Control
 Limits and the Parameter Quality Control Limits.



****************************** WARNING MESSAGES ******************************


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South Carolina Water Resources Commission
Water Quality Laboratory Report

SCWRC No.: 36B-b007
Field No.: CRK-65
Owner s Name: Archie Deal, Jr.
City: Blacksburg
Date Collected: 04/09/86
Project: Vulcan
Water Type: GW
Aquifer Code: km
County: Cherokee
Latitude: 350918
State: SC
Time Collected: 1315
Project No.: 2004
Requested By: Mitchell
Analysis Code Requested: 1000
Lab No.: 86-110-001
Longitude: 812624
Address: Rt. 3
Zip: 29702
Collected by: HLM/DTC
Water Use: DO
Office: 06
Field Remarks: Tap at west end of mobile home

FIELD MEASUREMENTS

Parameter	Value	Units	Parameter	Value	Units
Depth	0	Feet	Conductivity	85	umho/cm2
pH, Field	7.3	SU	Temp. Field	16.9	C
DO, Field	0.00	mg/L	Alk., Field	51.5	mg/L

LABORATORY RESULTS

Parameter	Concentration	Units	Parameter	Concentration	Units
Acidity	0.0	mg/L	Calcium, Tot.	14.5	mg/L
Alkalinity	57.3	mg/L	Calcium, Dis.	14.3	mg/L
Chloride	1.1	mg/L	Iron, Tot.	177	ug/L
Spec. Cond.	101	umho/cm2	Iron, Dis.	16	ug/L
Fluoride	0.09	mg/L	Magnesium, Tot.	2.81	mg/L
Hard. Calc.	47	mg/L	Magnesium, Dis.	2.79	mg/L
Nitrate	0.0	mg/L	Manganese, Tot.	10	ug/L
pH, Lab.	7.23	SU	Manganese, Dis.	2	ug/L
Phos., Ortho.	0.00	mg/L	Potassium, Tot.	0.34	mg/L
Tot. Dis. Sol.	58	mg/L	Potassium, Dis.	0.31	mg/L
Sulfate	2.0	mg/L	Silica, Dis.	16.47	mg/L
			Silicon, Dis.	7.70	mg/L
			Sodium, Tot.	2.0	mg/L
			Sodium, Dis.	1.9	mg/L

More like 72

aboratory Remarks:

OFFICAL USE ONLY: This laboratory analysis cannot be used to satisfy any private contractual obligations.
This analysis should not be construed to mean that this water is potable, for that determination consult the S.C. Department of Health and Environmental Control.

Date Completed: 07/14/86
Date Released: 07/14/86

By: Lawrence H. [illegible]
Chief Chemist

S.C.D.H.E.C. Laboratory Id. No. 40006
Issued: December 5, 1983

S.C.D.H.E.C. Certification No. 80001
Expires: December 5, 1986

S. C. WRC Lab Report Version 03-86

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                        QUALITY CONTROL REPORT
  SCWRC Number : 36B-b007
.oratory Sample No.: 86-110-001       Water Quality Record Number :        2

******* Water Quality Parameters Exceeding Drinking Water Standards ********

l parameters are below the drinking water limit.

****************************** IONIC BALANCE ******************************

                          CATIONS

solved Calcium =     14.3      Millequivalents Calcium   =     0.71357
solved Iron    =     16        Millequivalents Iron    =   0.00085952
solved Magnesium =    2.79     Millequivalents Magnesium  =   0.2295054
solved Manganese =     2       Millequivalents Manganese =   0.0000728
solved Potassium =    0.31     Millequivalents Potassium    =  0.0079267
solved Sodium   =    1.9       Millequivalents Sodium    =   0.08265

otal Cation Millequivalents =  1.03458442

                          ANIONS

lkalinity   =    57.3          Millequivalents Alkalinity  =    0.939147
hloride     =      1.1         Millequivalents Chloride  =   0.031031
luoride     =   0.09           Millequivalents Fluoride  =   0.0047376
itrate      =   0.0            Millequivalents Nitrate  =   0.000000
otal Phosphorus =    0.00      Millequivalents Tot. Phos   =   0.0000000
ulfate =      2.0              Millequivalents Sulfate   =   0.041640

otal Anion Millequivalents =   1.0165556
---------------------------------------------------------------------------
otal Millequivalents =   2.05114002
ifference (Cations - Anions) =   0.01802882

IONIC BALANCE   =   0.87896583
---------------------------------------------------------------------------

****** Description of the Precision of this Water Quality Analysis ******
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ave been determined and the results are with USGS Ionic Balance Control
mits and the Parameter Quality Control Limits.



**************************** WARNING MESSAGES ****************************
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APPENDIX B - WELL DESCRIPTIONS

SCWRC GRID#	COUNTY NUMBER	ELEV	LAT	LONG	WELL USE	WELL TYPE	TOTAL DEPTH	CASG DEPTH	CASG DIAM	YIELD GPM	SWL	SWL DATE	COMP DATE	DRILLER	REMARKS
36B-a001	CRK-0093	825	350902	812558	IS	D	101	-1	6	-1	35.90	32586		Faulkner	
36B-a002	CRK-0094	820	350906	812555	DO	D	97	70	2	-1	-1.00		1965	McCall Bros.	owner says well 2"
36B-b001	CRK-0059	825	350922	812642	UN	D	305	89	6	1	51.40	32186	3/84	Arnold's	
36B-b002	CRK-0060	810	359921	812645	DO	D	145	135	6	20	47.75	32186	4/84	Arnold's	
36B-b003	CRK-0061	790	350931	812653	UN	D	400	-1	6	-1	27.50	32186		Faulkner	
36B-b004	CRK-0062	795	350932	812653	UN	D	140	-1	6	-1	51.70	32186		Faulkner	caved in at 30'
36B-b005	CRK-0063	795	350933	812652	DO	D	133	-1	6	-1	-1.00			Faulkner	
36B-b006	CRK-0064	790	350919	812626	AR	D	405	88	6	-1	54.75	32186	8/84	Arnold's	SCWRC obs. well
36B-b007	CRK-0065	770	350918	812624	DO	B	75	75	24	-1	33.00	32186	9/85	Arnold's	
36B-b008	CRK-0066	740	350917	812621	DO	D	265	75	6	3	97.00	32186	3/81	Arnold's	
36B-b009	CRK-0079	775	350927	812653	UN	B	-1	-1	24	-1	20.70	32186			
36B-b010	CRK-0068	770	350924	812652	DO	B	100	100	24	-1	13.75	32186		Arnold's?	
36B-b011	CRK-0069	780	350924	812649	DO	D	365	20	6	5	-1.00		1982	Faulkner	
36B-b012	CRK-0070	795	350922	812648	DO	D	-1	-1	6	21	-1.00		?	Faulkner	drilled 82-84 maybe
36B-b013	CRK-0071	785	350916	812645	DO	D	225	94	6	4	43.58	32186	6/80	Arnold's	
36B-b014	CRK-0072	810	350918	812638	DO	B	65	65	24	-1	55.70	32186	5/80	Arnold's	
36B-b015	CRK-0073	810	350918	812638	DO	D	165	95	6	6	57.85	32186	4/82	Arnold's	
36B-b016	CRK-0074	825	350918	812634	DO	D	265	99	6	3	76.00	32186	3/81	Arnold's	
36B-b017	CRK-0075	800	350920	812632	DO	D	245	-1	6	10	74.15	32186	8/84	Faulkner	
36B-b018	CRK-0076	790	350920	812630	DO	D	185	85	6	7	67.00	32186	3/81	Arnold's	
36B-b019	CRK-0077	765	350914	812626	UN	B	76	76	24	-1	63.00	32186	6/81	Arnold's	15' of water
36B-b020	CRK-0078	775	350926	812653	DO	B	48	48	24	-1	20.25	40986	7/82	Arnold's	
36B-b021	CRK-0080	730	350912	812622	DO	B	50	50	24	-1	30.50	32186	2/84	Arnold's	
36B-b022	CRK-0081	790	350917	812629	UN	D	405	117	6	-1	47.62	32186	8/82	Arnold's	WL taken by us 3/86
36B-b023	CRK-0082	780	350918	812627	DO	D	325	83	6	2	46.00		8/82	Arnold's	WL info from driller
36B-b024	CRK-0083	810	350922	812645	DO	D	140	-1	6	-1	-1.00				
36B-b025	CRK-0102	860	350936	812659	DO	D	115	-1	6	-1	-1.00		1964	Faulkner	
36B-b026	CRK-0103	910	350941	812659	DO	D	236	-1	6	12	-1.00			Faulkner	redrilled 1982
36B-b027	CRK-0106	750	350923	812626	UN	D	305	81	6	1	-1.00		5/83	Arnold's	lat/long uncertain
36B-b030	CRK-0109	825	350918	812634	AB	D	-1	-1	6	-1	-1.00				lat/long uncertain
36B-b031	CRK-0110	770	350924	812652	AB	B	-1	-1	24	-1	-1.00				lat/long uncertain
36B-c001	CRK-0067	805	350927	812701	AR	D	405	66	6	1	40.10	32186	5/80	Junior Setzer Co.	SCWRC obs. well(ADR)
36B-c002	CRK-0084	830	350933	812700	DO	D	150	-1	6	-1	-1.00			Kuilev Herron	
36B-c003	CRK-0096	790	350923	812700	DH	D	-1	-1	-1	-1	-1.00				
36B-c004	CRK-0097	790	350923	812700	UN	D	-1	-1	6	-1	27.70	32586			
36B-c005	CRK-0098	790	350921	812700	DO	D	300	-1	6	-1	-1.00				buried 2' undergrnd
36B-c006	CRK-0099	910	350941	812701	UN	D	170	-1	6	12	72.00	32586	1960	Southeastern	silted up 50'
36B-c007	CRK-0100	910	350941	812701	DO	D	145	96	6	50	70.00	32586	5/85	Junior Setzer Co.	
36B-c008	CRK-0101	900	350940	812703	DO	D	230	-1	6	-1	-1.00				

SCWRC GRID#	COUNTY NUMBER	ELEV	LAT	LONG	WELL USE	WELL TYPE	TOTAL DEPTH	CASG DEPTH	CASG DIAM	YIELD GPM	SWL	SWL DATE	COMP DATE	DRILLER	REMARKS
36B-h001	CRK-0104	825	350852	812716	UN	D	165	-1	6	-1	81.00	32586	1957	Southeastern	
36B-h002	CRK-0105	830	350854	812713	DO	D	265	160	6	8	-1.00		9/85	Faulkner	
36B-h003	CRK-0111	770	350854	812702	DO	B	-1	-1	24	-1	-1.00				
36B-i001	CRK-0086	745	350834	812643	DO	D	245	10	6	2	20.00	32586		Faulkner	well 10-15 yrs old
36B-i002	CRK-0087	770	350843	812628	DO	B	-1	-1	-1	-1	38.70	32586	1974	Faulkner	
36B-i003	CRK-0088	800	350849	812620	DO	B	60	60	24	-1	53.80	32586			
36B-i004	CRK-0089	800	350849	812620	DO	B	65	60	24	-1	-1.00				
36B-i005	CRK-0090	800	350850	812618	DO	D	80	-1	6	-1	47.20	32586	1970	Faulkner	
36B-i006	CRK-0091	800	350856	812612	IS	D	300	-1	6	-1	58.70	32586		Faulkner	redrilled. >300'
36B-i007	CRK-0092	720	350829	812612	DO	O	65	-1	-1	-1	0.00				Mr. Moore. caretaker
36B-i008	CRK-0112	800	350853	812614	DO	D	-1	-1	6	-1	-1.00				
36B-j001	CRK-0095	780	350853	812534	DO	H	50	50	30	-1	40.00	32586		dug. older than 1945	

Heading Abbreviations: **SCWRC GRID#** S.C. Water Resources Commission well-grid number; **COUNTY NUMBER** sequentially assigned well identification number for this county; **ELEV** elevation in feet above mean sea level, estimated from Grover 7-1/2" U.S. Geological Survey topographic map; **LAT** latitude; **LONG** longitude; **WELL USE** well use (**AB** abandoned; **AR** automatic recording observation well; **DH** dry hole; **DO** domestic; **IS** institutional; **UN** unused); **WELL TYPE** well construction (**O** open: usually subdivided into following types: **B** bored; **D** drilled; **H** hand-dug); **TOTAL DEPTH** depth of well in feet; **CASG DEPTH** casing depth in feet; **CASG DIAM** casing diameter in inches; **YIELD GPM** well yield in gallons per minute, as reported by driller or owner; **SWL** static water level in feet below land surface; **SWL DATE** date static water level measured; **COMP DATE** drilling completion date.

Note: -1 indicates data unknown.