INVESTIGATION OF GROUND-WATER CONDITIONS AT GORETOWN, IN EASTERN HORRY COUNTY, SOUTH CAROLINA

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ABSTRACT

Two coquina mines operating near Goretown, in eastern Horry County, South Carolina, have been suspected of causing or contributing to reported water level declines in domestic wells in the surrounding area. An investigation of the reports included inventorying wells in the study area, measuring water levels in observation wells and domestic wells, and determining the ground water conditions at each mine.

Ground-water withdrawals by the mines have lowered water levels sufficiently to have affected some of the domestic wells adversely. The area northwest of the mining activity and the Daisy Scarp has the greatest number of reported well problems. A recharge trench designed to maintain normal ground-water levels outside the perimeter of the southeastern mine, known as the No. 9 Mine, is of questionable effectiveness.

Recommendations include: (1) installation of additional observation wells the north and west of the mines, where the majority of well problems have been reported and observation wells are sparse; (2) placement of staff gages in each mine, to monitor the depth to which water is lowered; and (3) continued monitoring of ground-water usage, including the quantities of water pumped and discharged off the site.

INTRODUCTION

This investigation was made because of concerns expressed by Goretown residents over water level declines in domestic wells. Operating in this area are two mines, the Horry County Mine and No. 9 Mine, which pump large quantities of ground water in order to quarry limestone. The study area is located in eastern Horry County, near the North Carolina - South Carolina boundary (Fig. 1). Both mines were visited during late August 1988, to inventory wells, measure ground-water levels, and view the hydrologic conditions (Fig. 2).

BACKGROUND

The Horry County Department of Public Works first began mining coquina (a loose, shelly limestone used for roadbeds and other construction) in the area in 1983. Ground water is pumped out of the pits to maintain the water level below the working surface of the mine, allowing the coquina to dry out before removal by driving pans across the surface. Currently the Horry County Mine has two pumps, an 18-inch turbine pump with a rated capacity of 5,100 gpm (gallons per minute) and a 6-inch suction pump rated at 350 gpm. Roger Shannon, the site supervisor, reported to the author, during a visit to the mine on August 22, 1988, that the 18-inch turbine pump generally is run for several hours twice a week to provide pond water for a local resident. The working surface of the mine was dry at the time of the author's visit.

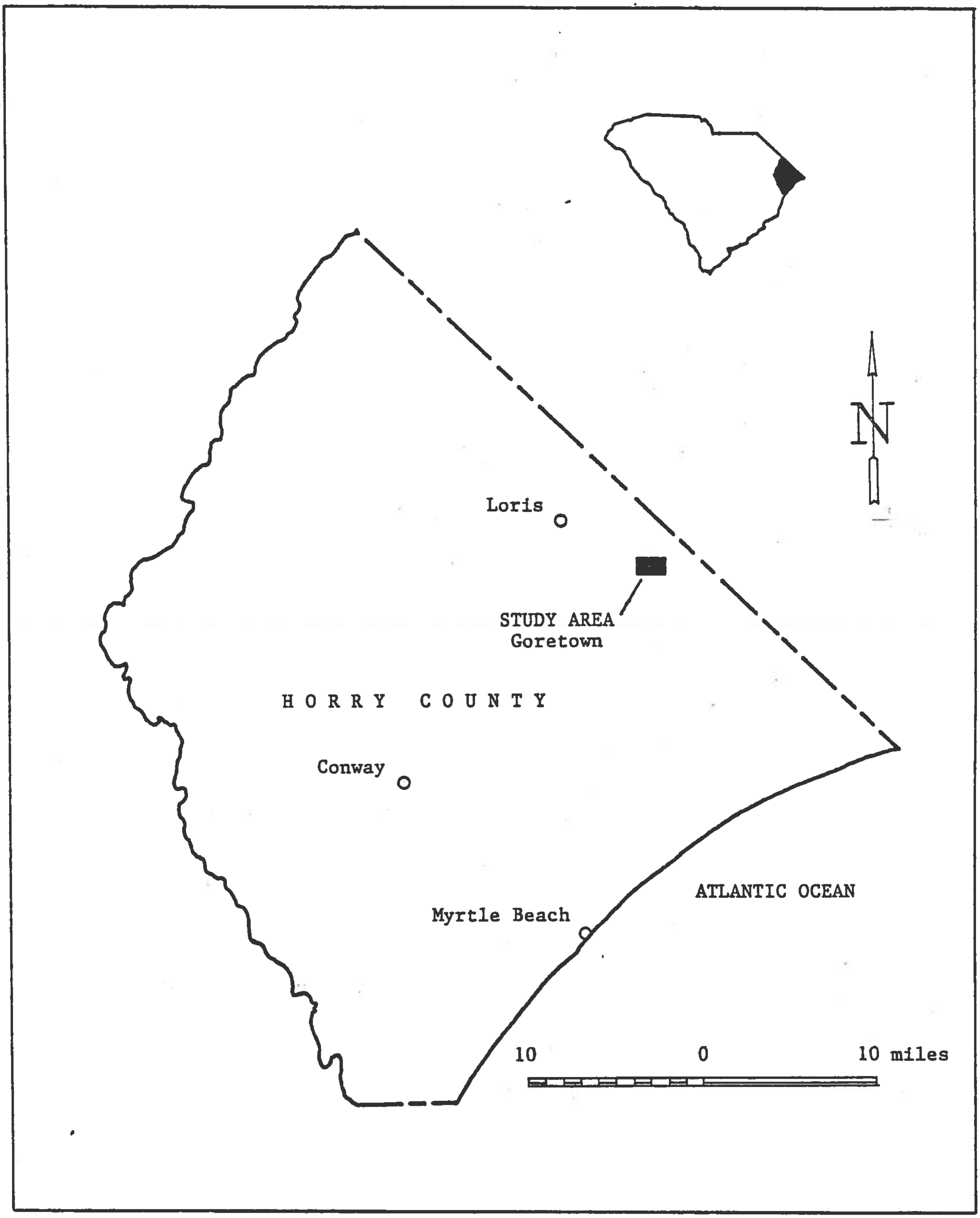

Figure 1. Location of study area.

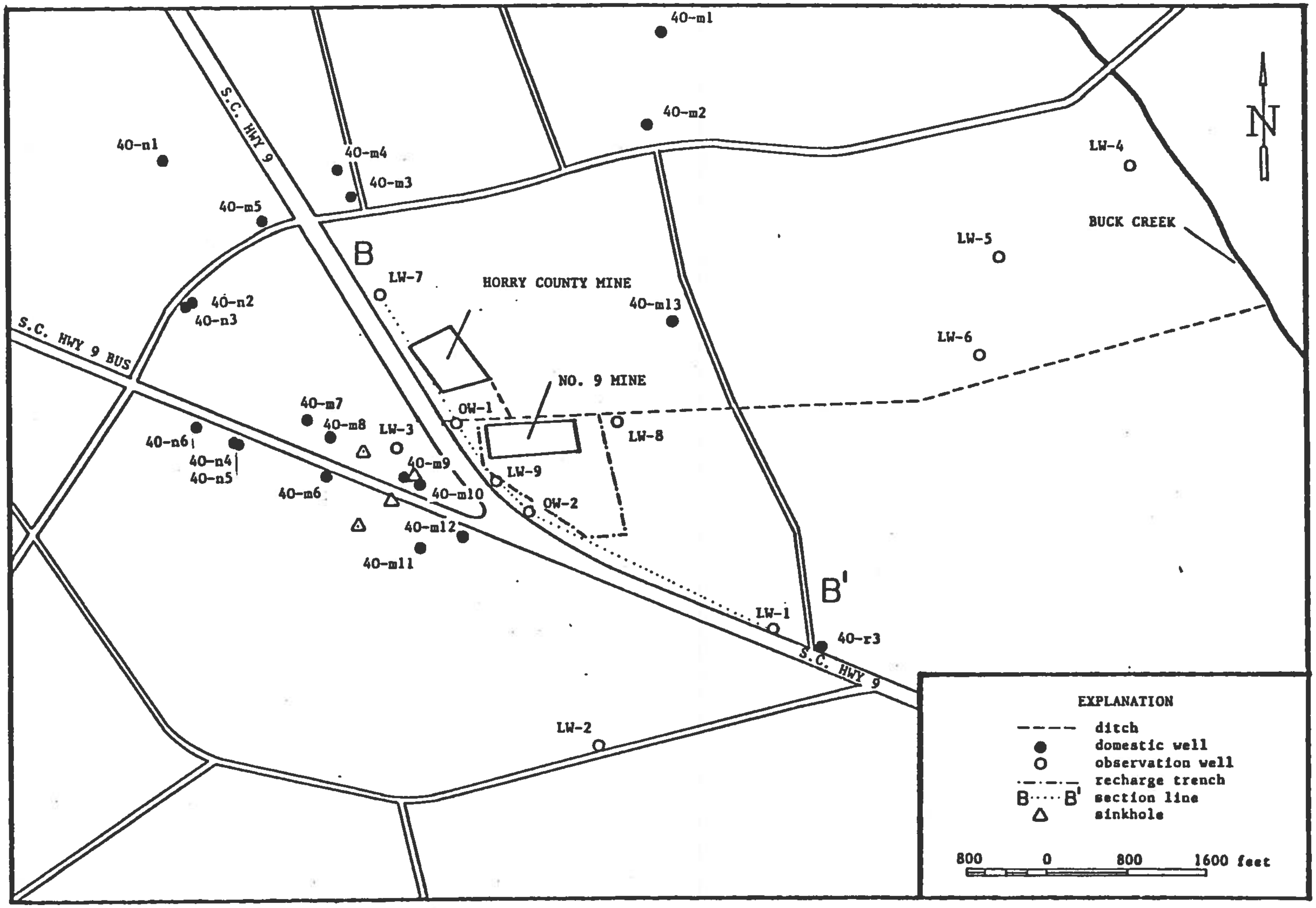

Figure 2. Well locations and natural features.

Originally, a recharge trench was constructed in the upper 3 feet of the coquina at the Horry County Mine to minimize dewatering effects and the potential for sinkhole development in the surrounding area. This trench was one of the requirements established by the South Carolina Land Resources Conservation Commission (LRCC) for the County's mining permit.

The South Carolina Water Resources Commission is currently processing the County's application (dated August 30, 1989) for a Ground-Water Use Permit to withdraw 2,500,000 gpd (gallons per day) by means of a 16-inch turbine pump rated at 2,900 gpm. A hydrogeological report of the County Mine and surrounding area by HDR Engineering, Inc. has been submitted, as required by the letter of concurrence issued on September 13, 1988. This report included, among other things, all available hydrogeologic information and a discussion of the abatement procedures that are to be implemented in the event of any unreasonable adverse effects on water use or users as a result of the mining operations.

The No. 9 Mine, located 250 feet southeast of the Horry County Mine, began operations in May 1986. Ground water is lowered to within a few inches of the working surface to allow the pans to remove the material and prevent it from drying out and becoming hard. Two pumps are located in the pit: a 10-inch centrifugal pump capable of withdrawing 5,000 gpm, mounted on a floating pontoon in the pit which allows it to move with changes in water level; and a mobile, centrifugal pump (capacity unknown).

A Ground-Water Use Permit for the No. 9 Mine was applied for on February 7, 1986. Processing of this application was delayed as a result of the development of a 45-foot diameter sinkhole 1,300 feet southeast of the mine and a subsequent investigation into the probable cause. This was the second sinkhole known to have developed since mining began in the area (Fig. 2). To the northeast, two smaller sinkholes have since been reported to have developed by mid-January 1989. Hockensmith and Pelletier (1987) concluded that the probable cause for land surface collapses was declining water levels resulting from mine-dewatering activities and that additional sinkholes were likely to occur if uncontrolled ground-water pumping continued.

A permit was granted June 2, 1987, for the No. 9 Mine to withdraw no more than 1,400,000 gpd from a pump rated to produce 1,000 gpm. Special conditions of the permit include quarterly ground-water measurement of nine observation wells and the submittal of copies of any hydrogeological studies of the mine. A hydrogeologic assessment has been completed by Soil & Material Engineers, Inc.

A recharge trench was constructed along the east, south, and west perimeter of the mine property, as per LRCC requirements. Five shallow observation wells in the immediate vicinity of the No. 9 Mine, and six others located at various distances from the mine, were constructed (Table 1). Water levels in these wells are measured monthly.

Table 1. Observation-well construction

WELL NO.	TOTAL DEPTH (feet)	SCREEN SETTING (depth in feet) TOP	BOTTOM
OW-1	47	unknown	unknown
OW-2	50	unknown	unknown
LW-1	45	33	43
LW-2	55	22.5	32.5
LW-3	45	18	28
LW-4	30	15	25
LW-5	30	16.5	25.5
LW-6	30	18	28
LW-7	52	28	38
LW-8	30	14	24
LW-9	30	10.25	20.25

SITE GEOLOGY

The site under investigation is located in the Lower Coastal Plain of South Carolina. It lies at the toe of the Daisy Scarp, which strikes northeast-southwest, bisecting Horry County. In this area, it is marked by a change in elevation from 40 feet on the east to 80 feet on the west (Fig. 3).

The study area is immediately underlain by sediments of Tertiary age. They are, in descending order, the Canepatch, Waccamaw and Duplin Formations. These sediments are underlain by the Peedee, Black Creek, Middendorf, and possibly the Cape Fear Formations, all of late Cretaceous age. A generalized hydrogeologic section has been prepared from auger boring data from the South Carolina Geological Survey (Figs. 4 and 5).

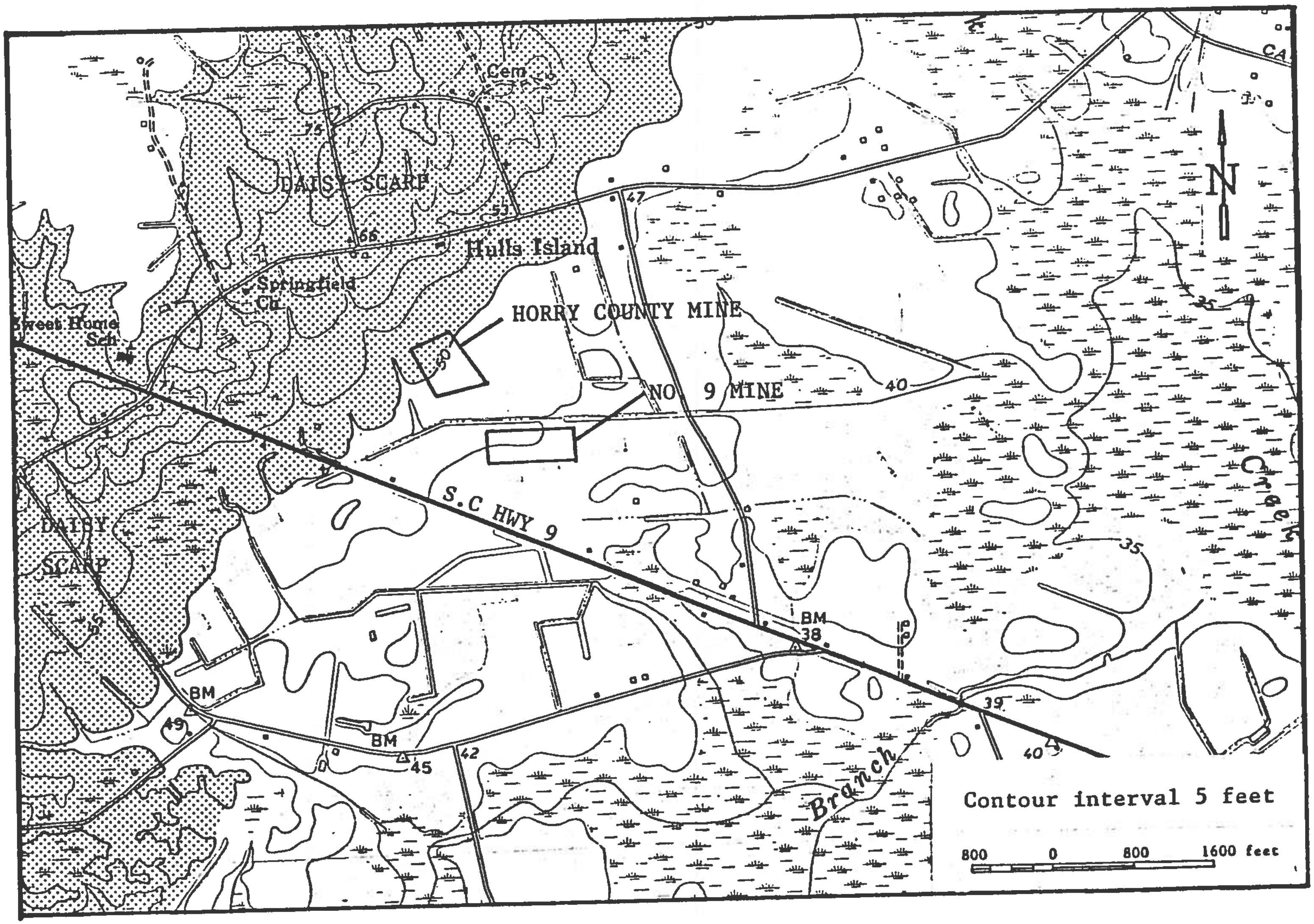

Figure 3. Topographic map of study area.

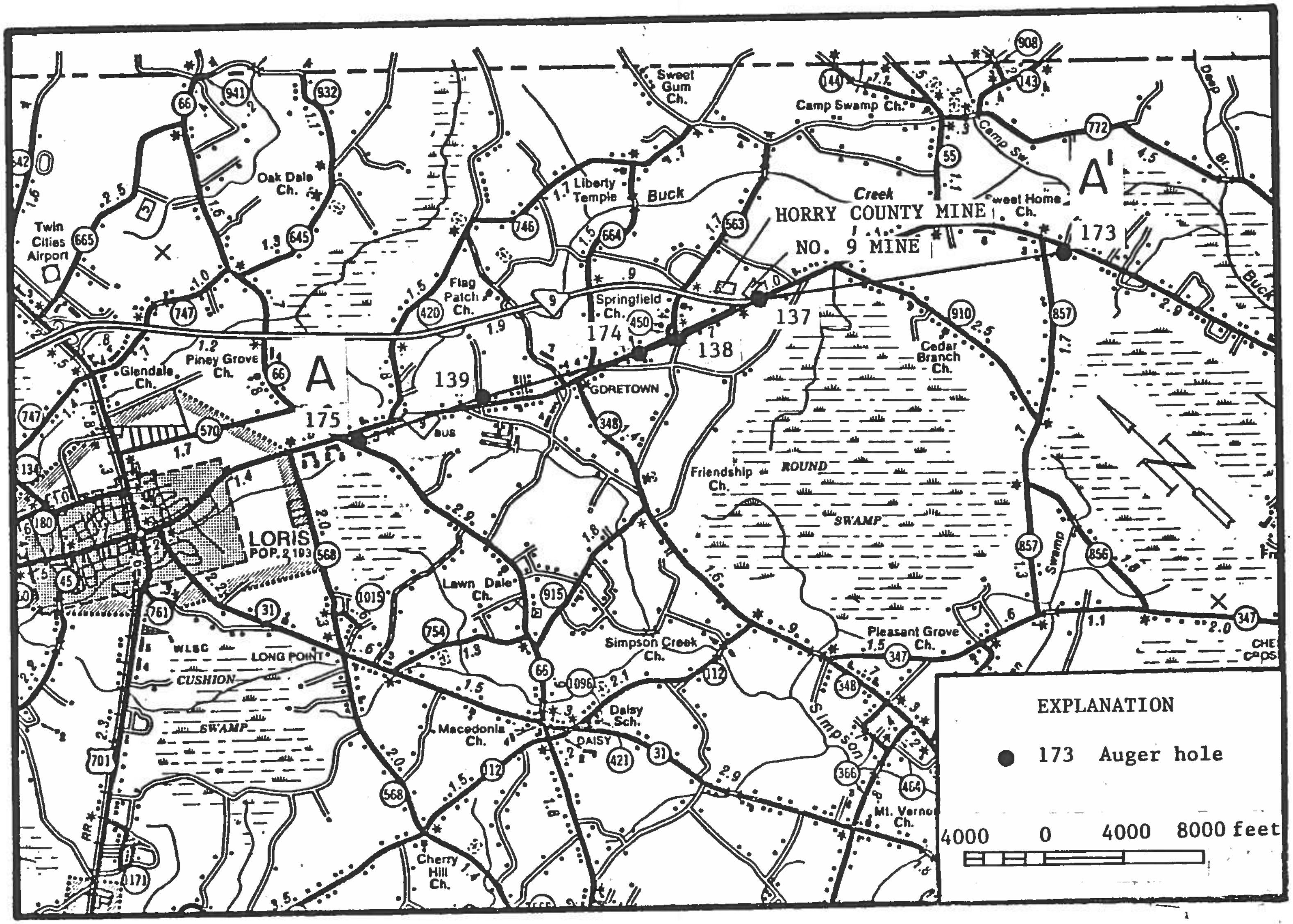

Figure 4. Location map for auger holes used in the hydrogeologic section A-A'.

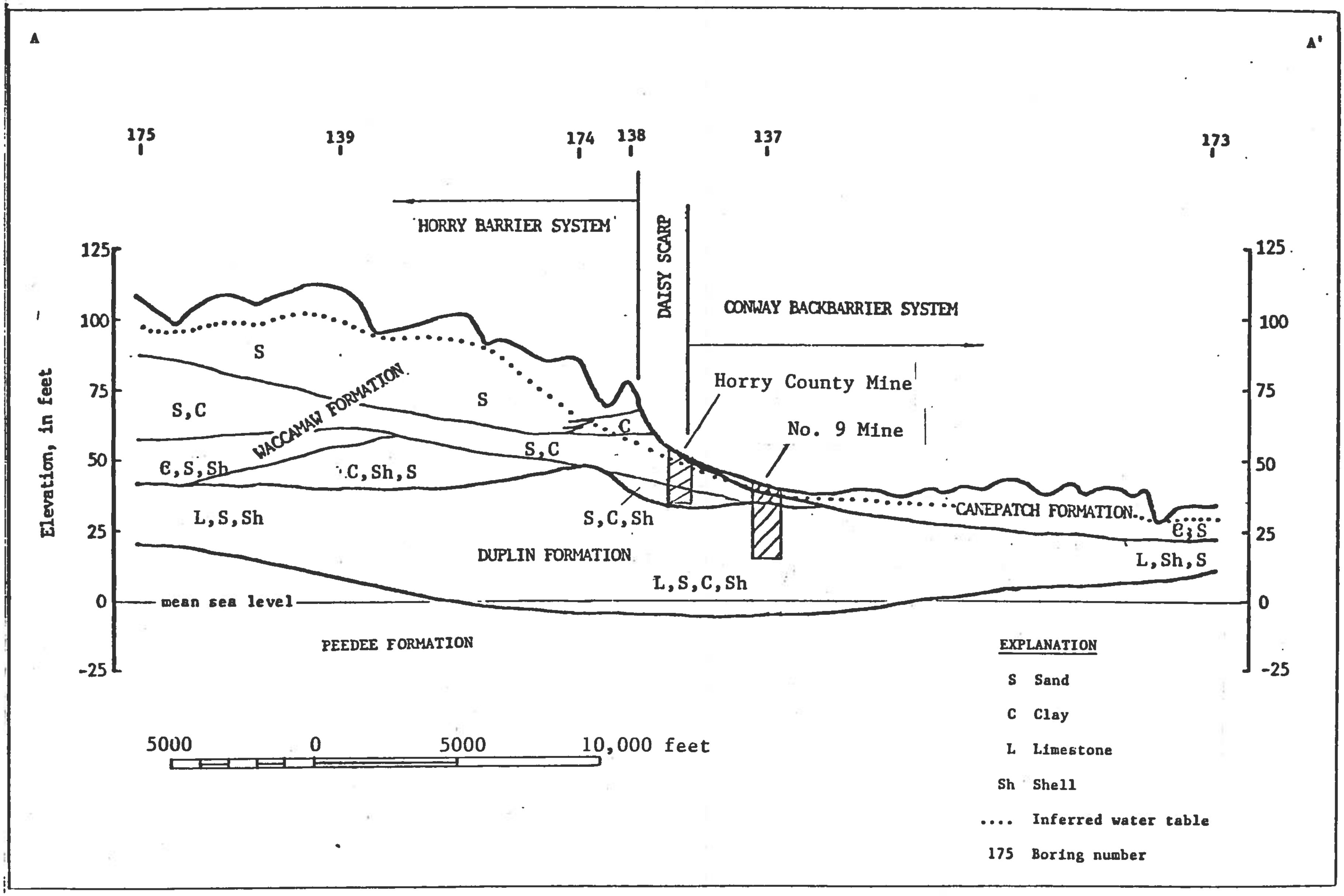

Figure 5. Hydrogeologic section A-A′ using South Carolina Geological Survey auger boring data.

The Canepatch, at this location, is part of the Conway backbarrier and composed of light-orange-brown and blue-gray, sandy clay. The clay is separated from the underlying Waccamaw Formation by an unconformity. Thickness of the Canepatch Formation ranges from 8 to 24 feet east of the scarp and 5 to 8 feet within the No. 9 Mine; it pinches out to the northwest under the Daisy Scarp (Soil & Material Engineers, 1987).

The Waccamaw Formation, which overlies the Duplin Formation, is composed of well-sorted, light-yellow-brown or blue-gray, very fine to medium sand grading downward to a blue-gray, shelly and sandy clay northwest of the Daisy Scarp. To the southeast these deposits grade into a combination of soft, shelly, clayey, and sandy limestones. West of the scarp, the formation thickness exceeds 30 feet, but it pinches out to the east (Fig. 5). Within the No. 9 Mine, it is approximately 5 feet thick (Soil & Material Engineers, 1987). Hydrogeologic section B-B' (Fig. 6), which runs roughly northwest-southeast, shows that the Waccamaw Formation is absent east of the No. 9 Mine. According to borehole data from Soil & Material Engineers, the elevation of the top of the Waccamaw, where it is present, ranges from about 36 to 42 feet above mean sea level (msl). The Waccamaw Formation is the chief source of the coquina extracted by the Horry County Mine.

The Duplin Formation is a very pure, dense, crystalline limestone that has been observed by local well drillers to contain numerous voids that may be seen in the highwalls of the No. 9 Mine. This formation is between 25 and 50 feet thick west of the Daisy Scarp, 6 to 40 feet thick just east of the scarp, and thinner with distance to the east. In the study area,

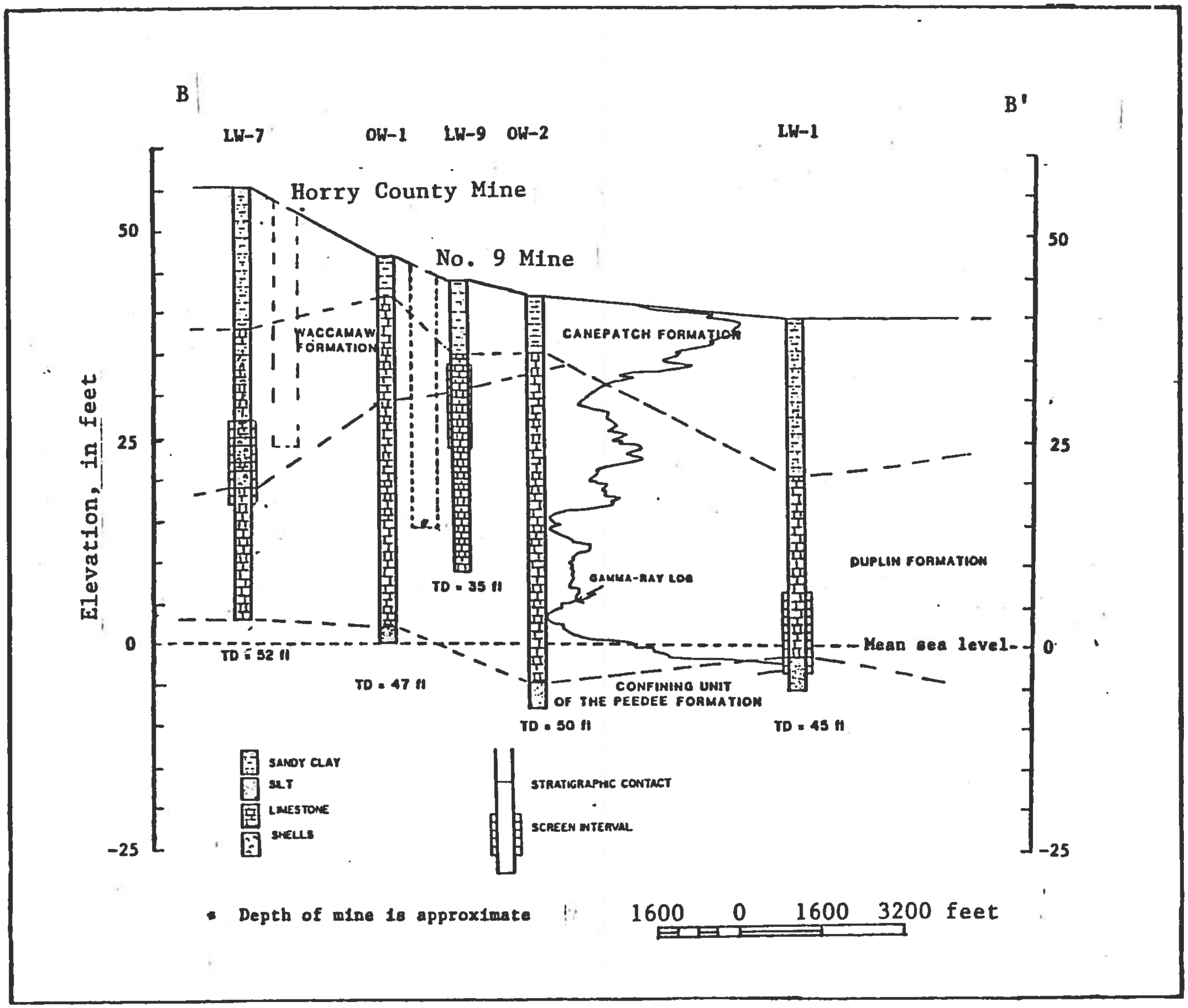

Figure 6. Hydrogeologic section B-B′ from LW-7 to LW-1 (modified from Soil & Material Engineers, 1987).

the elevation of the base of the Duplin varies from 15 to -12 feet msl. It is this formation that provides the majority of the limestone for the No. 9 Mine.

Additional information regarding the hydrogeology of this site may be obtained from DuBar(1971), Hockensmith and Pelletier(1987), or Soil & Material Engineers(1987).

HYDROLOGY

The principal surface water drainage is provided by Buck Creek, which flows southeast into the Waccamaw River near Longs. The local drainage net is connected to Buck Creek through a series of small tributaries and intermittent streams supplemented by farm and road ditches. A ditch located between the two mines currently receives discharge from both pits that then flows almost due east into Buck Creek (Fig. 2).

There are no water-level data available for wells prior to mining activity. Data from power-auger holes drilled by the South Carolina State Development Board, Division of Geology, during June and August 1965 and June 1966 (Fig. 5) indicate that ground-water levels were a subdued replica of the topography and ground water flowed to the southeast, perpendicular to the Daisy Scarp. The water table was 20 feet below land surface (bls) in auger hole 174 in June 1965 and 15 and 3 feet bls at auger holes 138 and 137, respectively, during late August 1965 (S.C. State Development Board, 1966).

The Waccamaw Formation directly overlies the Duplin Formation, and both formations are relatively permeable; therefore they are considered to be hydraulically connected. All overburden, mostly the Canepatch Formation, has been removed to allow access to the limestone formations within the mine boundaries. The limestone thereafter has no overlying confining layer, resulting in water-table conditions in the Waccamaw and Duplin Formations in the vicinity of the mines.

Potentiometric maps of these limestone aquifers for June and August 1987 and February, June, and August 1988 have been constructed (Figs. 7-11). For each of these dates, ground water flows toward the No. 9 Mine, with variations in the hydraulic gradients depending on the location.

Figure 7 represents water levels in the study area following a period of several weeks when the No. 9 Mine had been pumping water at a rate of 3,000 gpm (Soil & Material Engineers, 1987). The total volume of ground water displaced is not known, since pumpage was not reported to the SCWRC for this period. During this time, the water level was near the working surface of the pit, estimated at 25 feet msl. Analysis of this map shows that the hydraulic gradient was steepest, at 1.3 percent, from the northwest toward the mine. The gradient was less east, west, and south of the mine, with the lowest gradient, 0.2 percent, being from the east.

Figure 8 shows the potentiometric surface following a two-week period of no pumping by the No. 9 Mine, although the quantity of ground water withdrawn by the Horry County Mine is not known. Again the steepest hydraulic gradient was in the northwest. Water levels in observation

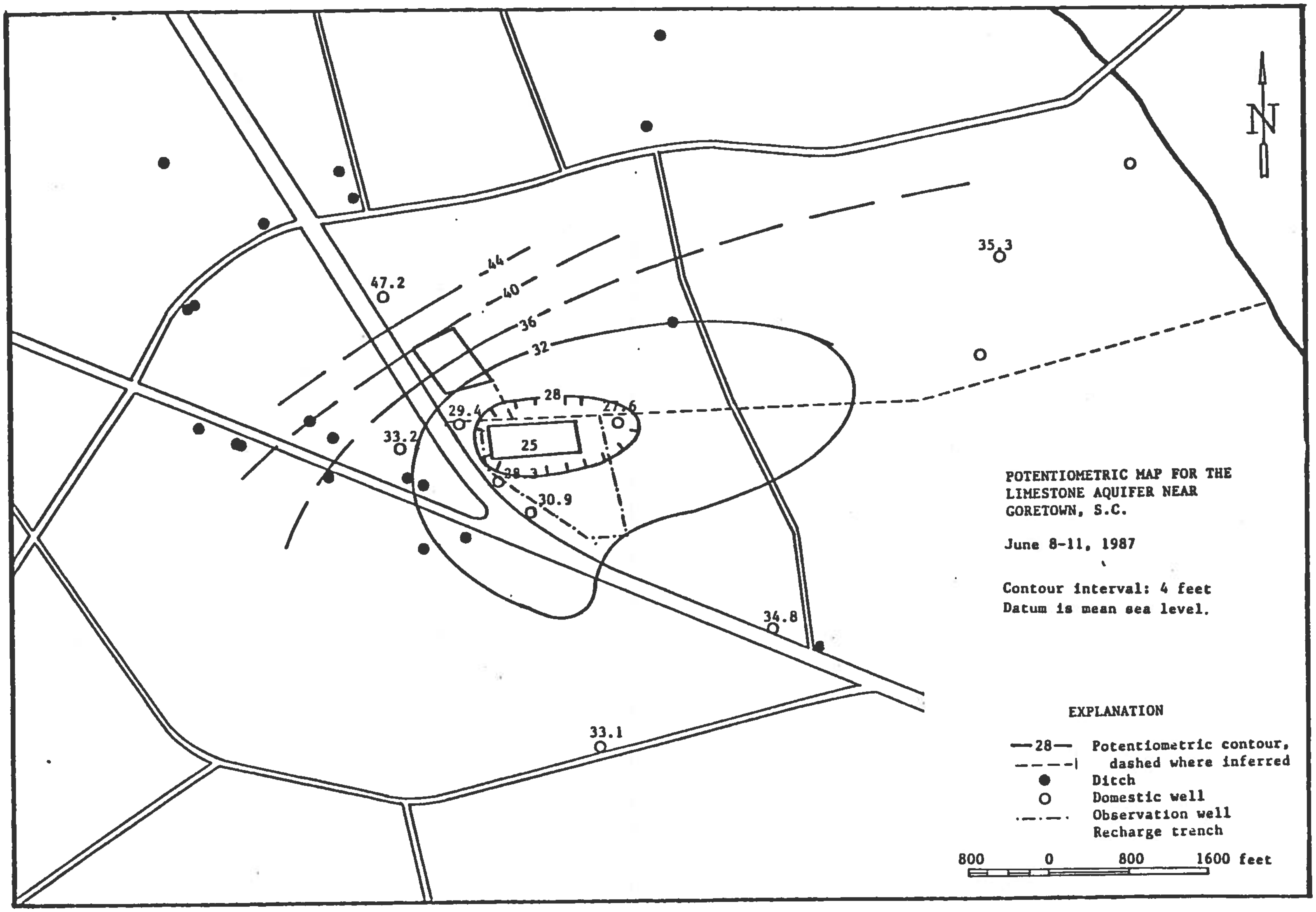

Figure 7. Potentiometric surface of the limestone aquifer,
June 8-11, 1987.

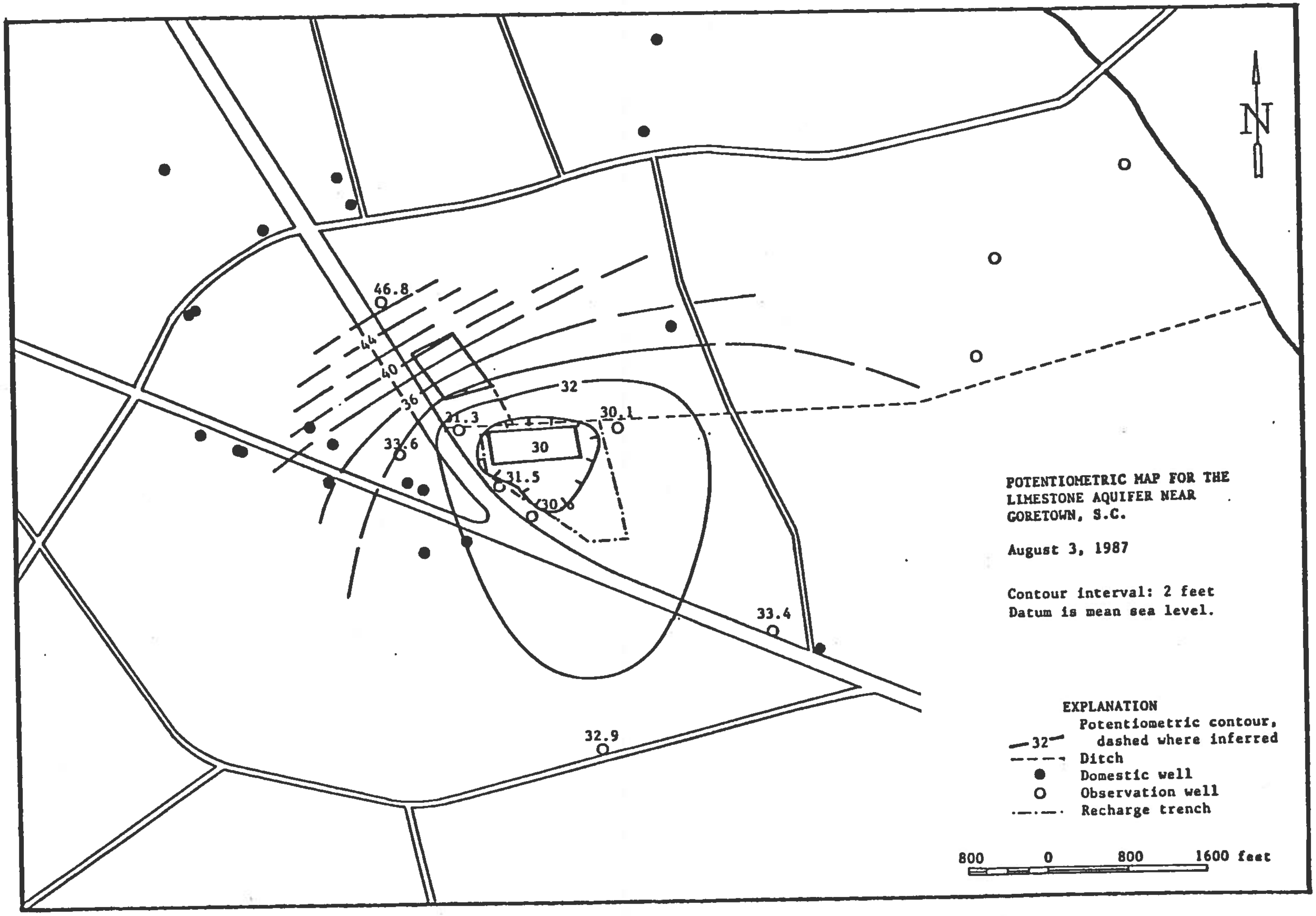

Figure 8. Potentiometric surface of the limestone aquifer, August 3, 1987.

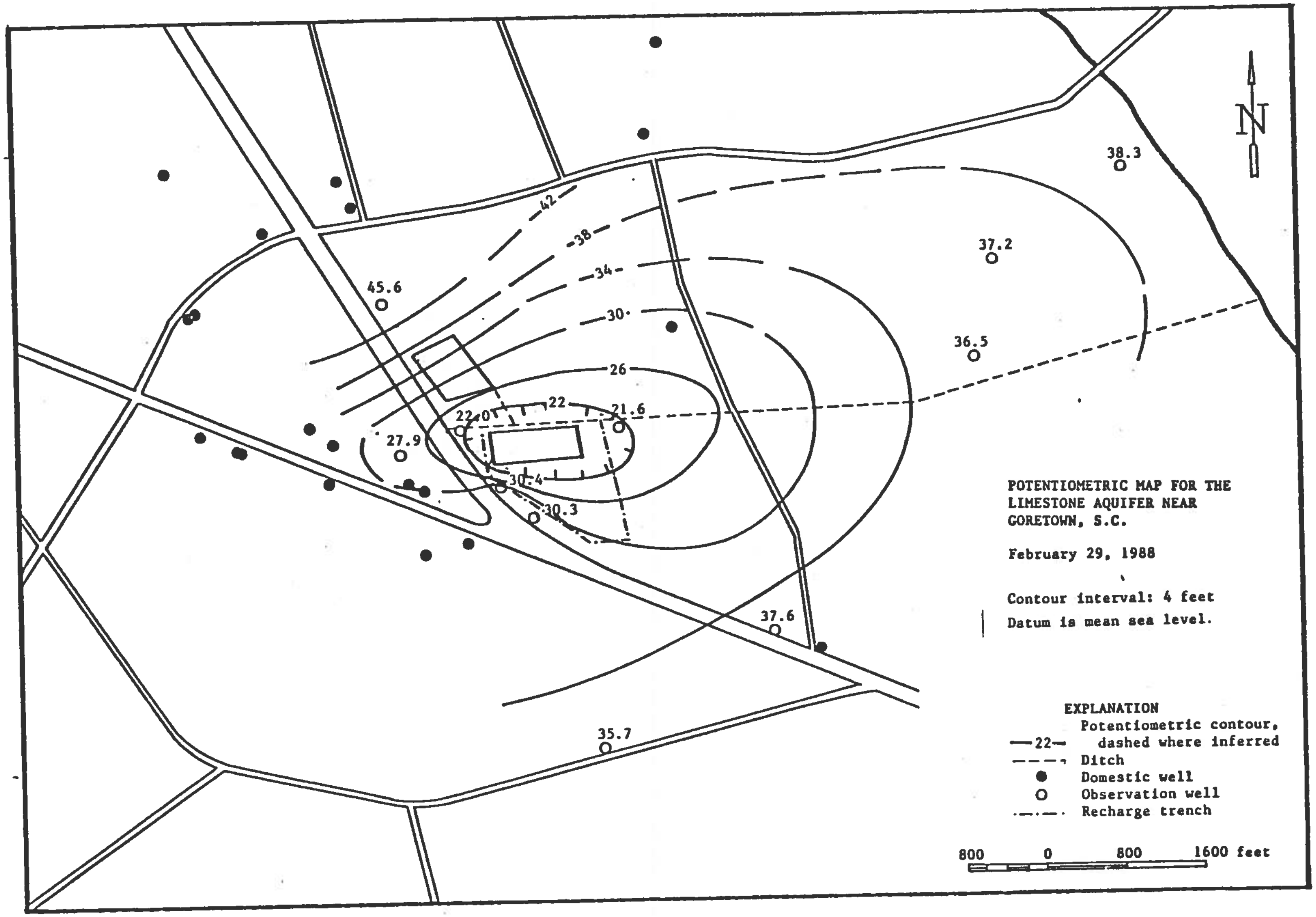

Figure 9. Potentiometric surface of the limestone aquifer, February 29, 1988.

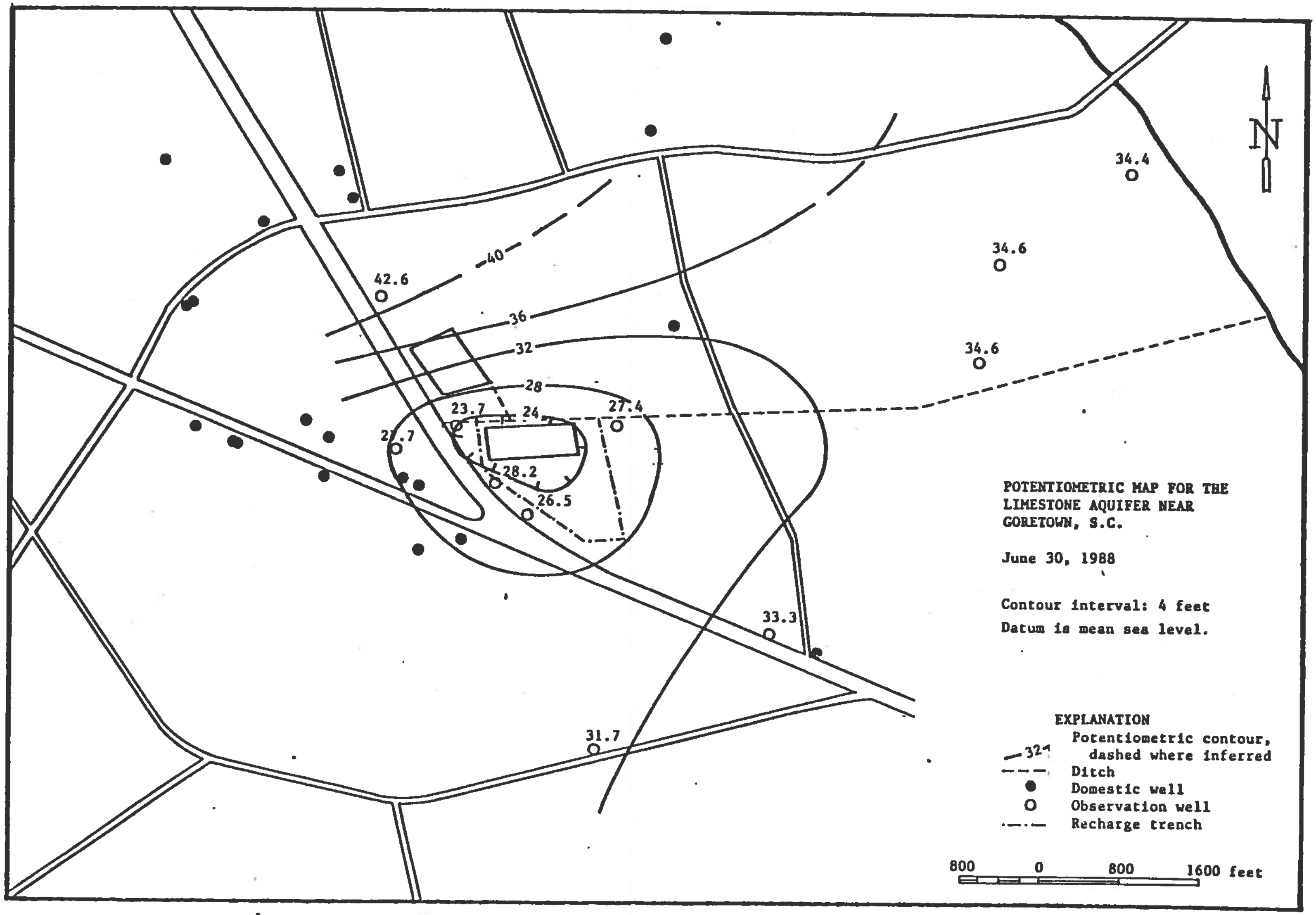

Figure 10. Potentiometric surface of the limestone aquifer, June 30, 1988.

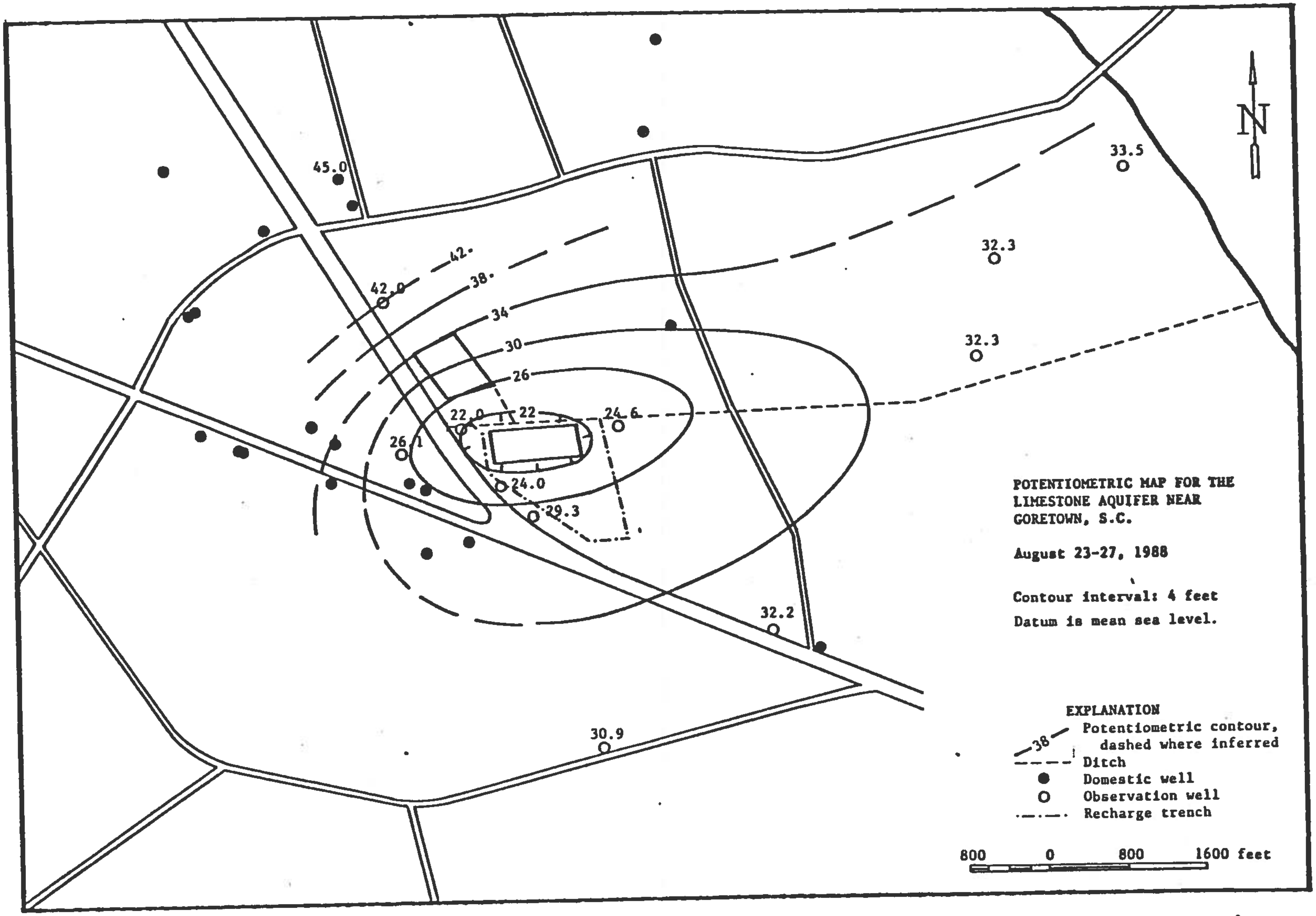

Figure 11. Potentiometric surface of the limestone aquifer, August 23-27, 1988.

wells in the immediate vicinity of the No. 9 Mine rose slightly, but in wells farther away the levels dropped by as much as 1.4 feet. A rise in water level of 5 feet had been estimated within the mine.

In Figures 9, 10, and 11, the water levels within the mines were unknown. Water level elevations of 22 feet msl or lower have been noted in at least one of the observation wells in the immediate vicinity of the No. 9 Mine for two of these maps, therefore it is likely that the water level within this mine was below 22 feet msl. Figure 9 represents ground-water levels in February 1988 following withdrawals of nearly 500 million gallons over a two-month period. Monthly water-use figures reported for the No. 9 Mine in 1988 are listed in Table 2. Roughly 300 million gallons were pumped during the two months prior to June 30, 1988 (Fig. 10). Ground-water withdrawals for July and August exceeded 430 million gallons. Withdrawals by the Horry County Mine for these periods are not known. These most recent maps are similar to the previously discussed maps in that the cone of depression was centered around the No. 9 Mine and the hydraulic gradient was generally steepest on the northwest. The steepest gradient of all five maps (approximately 3.6 percent) occurred from observation wells OW-2 and IW-9 toward the No. 9 Mine in February 1988 (Fig. 9). At that time the lowest gradients were south of OW-2 toward the mine and in the east at 0.2 and 0.4 percent, respectively. By June 1988, the lowest gradient, at 0.3 percent, occurred in the south and is only slightly less than the gradient in the east (Fig. 10). Northwest of the No. 9 Mine the gradient decreased to 1.2 percent. The gradient steepened slightly to 1.3 percent in August 1988 on the northwest (between observation wells OW-1 and IW-7) and the low gradient had shifted back to the east (Fig. 11).

The average hydraulic gradients for each map are listed in Table 3. Overall, the greatest fluctuation in the gradient occurs northwest of the pits, the direction of the regional recharge area and of the steepest gradient. Fluctuations are least in the east and the mean hydraulic gradient is equal east and south of the mined area.

Water levels in outlying observation wells dropped 2 to 4 feet from February to June 1988. Near the No. 9 pit, however, water levels were more variable. In OW-1 and LW-8, the potentiometric surface rose 1.7 and 5.8 feet, respectively, from February to June, whereas it declined 3.8, 2.2, and 0.2 feet in OW-2, LW-9, and LW-3, respectively, during the same period. From June to August 1988, there was a decline in the potentiometric surface in all the wells except OW-2, which rose 2.8 feet.

Near the No. 9 pit, water levels declined from 1.6 to 4.2 feet, whereas declines in outlying wells were between 0.6 and 2.3 feet. Water levels during August 1988 were the lowest recorded for all observation wells except OW-2.

Ground-water levels in wells near the mines may be affected by recharge from three sources; the recharge trench, the drainage ditch located along the northern edge of the No. 9 Mine, and a settling pond. Under normal operating conditions, ground water pumped from the No. 9 Mine is supposed to be discharged to a settling pond just outside the northeast corner of the pit. Water is then discharged from the pond into the recharge trench and circulated clockwise around the pit to the drainage ditch at the pit's northwest corner. Any remaining water then flows eastward toward Buck Creek. The trench is to remain full of water to

Table 2. Reported water use by the No. 9 Mine for 1988

MONTH	WATER USE (million gallons/day)
January	246.719
February	248.708
March	115.630
April	0.0
May	181.682
June	116.455
July	193.914
August	244.270
September	32.970
October	113.400
November	110.250
December	9.765
Total	1,613.763

Table 3. Summary of average hydraulic gradients

DATE	HYDRAULIC GRADIENT (percent) NORTHWEST	EAST	SOUTH
June 8-11, 1987	1.3	0.2	0.3
August 3, 1987	1.0	0.2	0.1
February 29, 1988	1.6	0.4	0.5
June 30,1988	1.2	0.4	0.3
August 23-27, 1988	1.3	0.3	0.5
Arithmetic mean	1.3	0.3	0.3

allow recharge to the ground, thereby maintaining higher ground-water levels outside the perimeter of the trench. If operated properly and if there is a hydraulic connection between the trench and the limestone formations, then recharge could occur along its entire length.

In addition to water from the recharge trench, the drainage ditch receives periodic discharge from the Horry County Mine. This ditch, and possibly the settling pond, may contribute recharge water to the subsurface. The recharge effects on the potentiometric surface depend upon the amount, frequency, and manner in which recharge is applied.

The rise in water levels in OW-1 and LW-8 and the changes in the hydraulic gradients from February to June 1988 may have been caused by recharge from the drainage ditch if the Horry County Mine pumped ground water during this time. Water levels rose in only these two wells, located near the ditch, whereas water-level declines were noted in the remaining wells. The recharge trench may not have been utilized or effective during this period, thus resulting in declines in water levels in OW-2 and LW-9. A site inspection by LRCC personnel documented on one occasion (March 9, 1988) that no water was in the recharge trench while the No. 9 Mine was dewatering the pit (Letter from Patrick Walker, LRCC, to Bill Griste, Bonzai, Inc. dated March 31, 1989).

A water-level rise in OW-2 by August 1988 was possible while declines were noted in OW-1 or LW-9 if water in the trench was not circulated to the northwest corner of the No. 9 Mine. On August 22, 1988, the recharge trench at the No. 9 Mine was being modified and had no water flow in the southwestern portion, but on August 23, 1988, water was flowing in the trench. The grade of the trench was being altered to facilitate clockwise flow around the mine; therefore, this explanation is reasonable.

An anomaly appears to exist in the potentiometric surface shown in Figures 8, 9, and 10 between LW-9 and OW-2. LW-9 is nearer to the No. 9 Mine than OW-2 but shows a higher water level than OW-2. This difference was least during February 1988 (0.1 foot) but increased to 1.7 feet during June 1988. A possible explanation is that the recharge trench may have been more effective in the vicinity of LW-9 than at OW-2, provided water was being discharged into the trench and circulated to the southwest side. Figure 11 for late August 1988 shows a lower water level in LW-9 than in OW-2, which is reasonable, considering the distance of the wells from the pumping center, particularly if recharge effects were minimal or altered during the recharge trench modifications. Further investigation is needed to determine the rate at which water is discharged into the trench and how effective the trench is at maintaining ground-water levels beyond the perimeter of the mine.

Hydrographs of selected observation wells and the cumulative departure from normal for precipitation at the Loris Station are shown in Figure 12. Water-level trends were consistent, with only minor variations among most of the observation wells. OW-1 differed noticeably from the other wells during late February 1988 and again in late June 1988. The low water level in OW-1 for February 1988 may have been a result of the well's proximity to the two mines and thus subject to pumping effects to a larger extent than other wells. The second discrepancy may have been a result of recharge from either the recharge trench or the ditch between the mines.

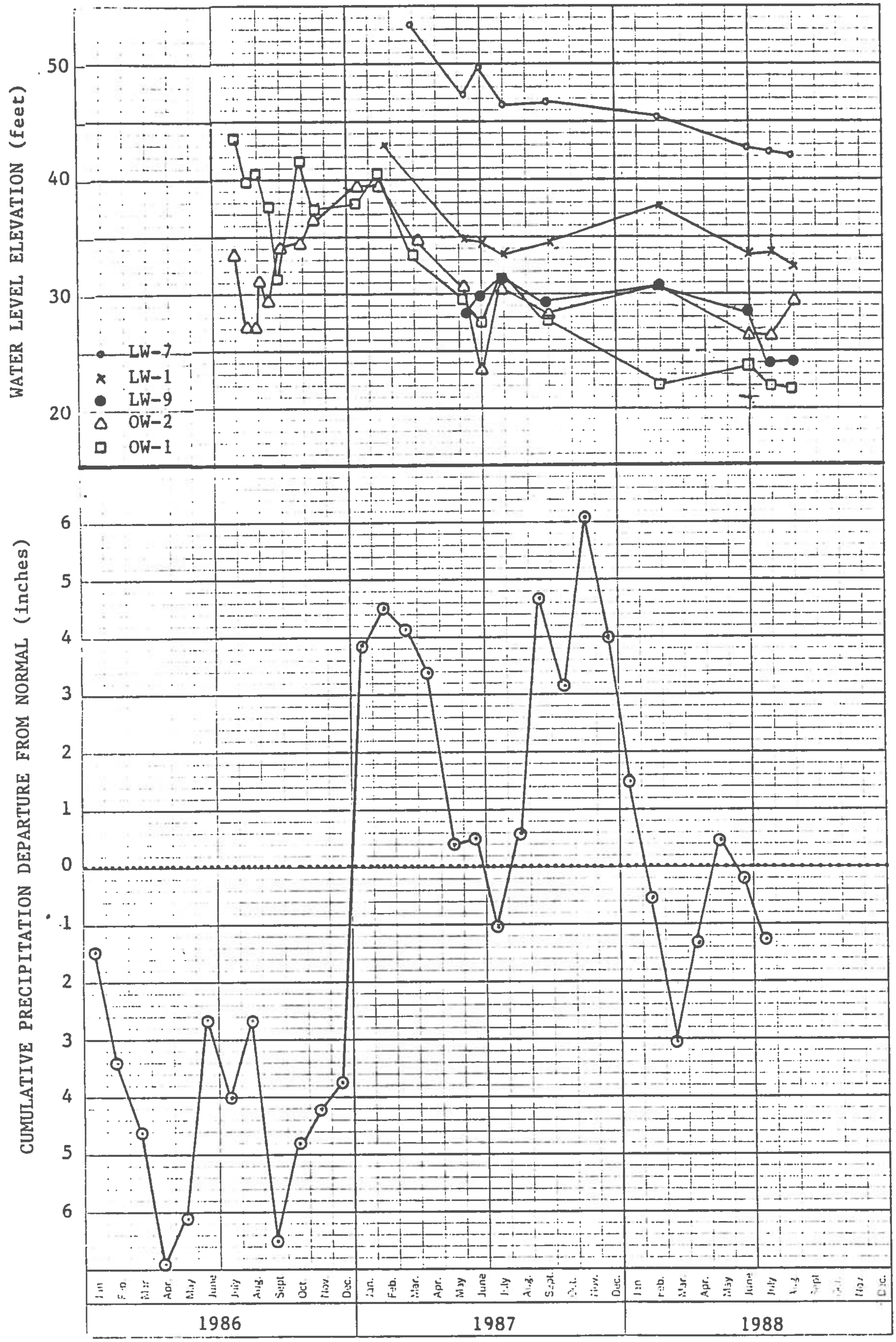

Figure 12. Hydrographs of selected observation wells and the cumulative departure from normal for precipitation at the Loris Station.

The hydrographs of the observation wells were similar to the plot of the precipitation data prior to July 1987. During the last six months of 1987, however, the water levels in the wells continued to drop or rose only slightly, while the precipitation departure was up to 6 inches above normal. The water-level trends also differed from the precipitation data during the first five months of 1988. Comparisons of the hydrographs with the monthly pumpage figures during 1988 for the No. 9 Mine indicated that the wells were greatly affected by the mine pumpage. These data tend to indicate that the effects of pumping mask the effects of precipitation.

REPORTED PROBLEMS

In addition to two sinkhole occurrences, residents have complained of domestic well problems caused by low water levels. These problems appear to have occurred infrequently prior to the summer of 1988, but since this time they have become common or very frequent. In general, the problems have been reported for shallow (less than 70 feet in depth) wells. Of the 21 domestic wells inventoried, 10 are known to be less than 60 feet deep. Complaints have been reported for half of these shallow wells and for two of the four wells with unknown depths. Table 4 lists these wells by Commission grid number and by latitude and longitude. In only one case could the water level in a domestic well with reported problems be measured. The water level in well 40-m4 was 24.92 feet below the measuring point on August 23, 1988, for an approximate elevation of 45 feet msl. This level is higher than was indicated in observation

Table 4. Selected wells in the Goretown area

WELL NO.	OWNER	LATTITUDE / LONGITUDE	DEPTH (feet)
40-m1	Johnson	34°01'45"/78°47'32"	42 r
40-m2	Johnson	34°01'37"/78°47'21"	261 r
40-m3	Hughes	34°01'31"/78°47'52"	65 r
40-m4	Springs	34°01'35"/78°47'54"	39.4 m
40-m5	Hughes	34°01'30"/78°47'57"	52 r
40-m6	Milligan	34°01'08"/78°47'55"	45 r
40-m7	Gerald	34°01'13"/78°47'25"	45 r
40-m8	Gerald	34°01'10"/78°47'25"	220 r
40-m9	Hardee	34°01'07"/78°47'46"	250 r
40-m10	Prince	34°01'07"/78°47'44"	unknown
40-m11	GoForth	34°01'00"/78°47'44"	unknown
40-m12	unknown	34°01'00"/78°47'32"	unknown
40-m13	Hillburn	34°01'20"/78°47'16"	210 r
40-n1	Hughes	34°01'37"/78°48'11"	55 r
40-n2	unknown	34°01'23"/78°48'10"00	16.5 m
40-n3	unknown	34°01'23"/78°48'10"01	unknown
40-n4	Milligan	34°01'12"/78°48'05"00	45 r
40-n5	Milligan	34°01'12"/78°48'05"01	45 r
40-n6	Milligan	34°01'13"/78°48'07"	210 r
40-r2	Strickland	34°00'52"/78°47'05"	220 r
40-r3	Strickland	34°00'52"/78°47'05"	220 r

r, depth reported; m, depth measured

well LW-7, which is nearer the mine, on August 27, 1988. It is, however, 25 feet below the top of the 1 1/2-inch casing, near the practical depth limit from which a suction-lift pumping system can withdraw water.

CONCLUSIONS

- Most of the reported domestic well problems exist in the northwestern portion of the study area, on the west flank of the Daisy Scarp. There are no observation wells in this area. It is possible that ground-water withdrawals have lowered the water table below an operational pumping level in these wells, because they are located higher in elevation than wells to the southeast. Shallow domestic wells with the most usage or demand are more likely to be affected by declining water levels because of their greater drawdowns.

- Ground-water levels during August 1988 are the lowest of all the data plotted. This may account for the increased frequency of domestic well complaints.

- The effects of the existing recharge trench are uncertain. There are some indications on the February 1988 and June 1988 potentiometric maps that recharge may be occurring near LW-9. Recharge from the ditch separating the County Mine and the No. 9 Mine is unsubstantiated; however, water-level data for OW-1 and LW-8 indicate that recharge may have occurred in June 1988.

- Comparisons of hydrographs for selected observation wells, precipitation data, and monthly pumpage figures for No. 9 Mine indicate that water levels in the vicinity of the mines are affected largely by the mine pumping and only minimally by variations in precipitation during periods of mine pumping.

RECOMMENDATIONS

1. Well soundings and water level measurements in the domestic wells should be made to determine if the reported well difficulties are 1) related to the limestone aquifer and 2) related to decreased water levels. Only the wells that are screened within or above the Duplin Formation, and whose reported problems appear unrelated to mechanical failure of the pump or to faulty well construction, should be considered in further investigations.

2. A staff gage should be installed at the pump location in each mine so that accurate water levels in the mines may be obtained.

3. A recharge trench should be constructed around the Horry County Mine. It may be feasible and economical for both mines if the existing recharge trench at the No. 9 Mine were to extend around the perimeter of the Horry County Mine. In addition, the trench may be most effective if located near the mine property boundaries, farthest from the center of pumping. This should reduce ground-water infiltration to the working surface of the

mines, while reducing the hydraulic gradient within the mine property, thus reducing erosion and the potential for sinkhole development.

4. Ground-water levels should be maintained no lower than 15 feet below land surface at the recharge trench. This value corresponds with the lowest water level indicated from auger boring data prior to mine development. This water level is also within the range of suction-lift pumps. If this water level is maintained, it would be above the top of the Duplin Formation in most locations.

5. Observation wells should be installed just outside the perimeter of the recharge trenches, where few or none currently exist. This should include a minimum of three wells located north, northeast, and east of the Horry County Mine.

6. Observation wells should be installed at various distances from the Horry County Mine. It is suggested that a minimum of three wells be installed from 1,600 to 2,000 feet west, north, and north-northeast of the mine.

7. Water-level measurements should be made monthly at all observation wells and staff gage locations and reported quarterly to the Commission. These data should be analyzed to determine if the recharge trenches are effective, if water levels are being maintained at the specified levels, and if these levels are adequate.

8. In the event that the recharge trenches prove to be ineffective, limitations on the depth to which the water level may be lowered in the mines should be considered. This may require changes in the type of mining conducted, such as converting a dry mining operation to a wet operation where very little ground water is removed.

REFERENCES CITED

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