TECHNICAL PUBLICATION SJ 80-9

EFFECTS ON THE FLORIDAN AQUIFER OF GROUND WATER WITHDRAWALS FOR FERNERY FREEZE PROTECTION, SOUTH-EAST PUTNAM COUNTY, FLORIDA

By

Frederick W. Ross

Water Resources Department

St. Johns River Water Management District

Palatka, Florida

November 1980

Project Number 2002309

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Drawdown and chemical data were collected from wells at two ferneries in Southeast Putnam County, Florida during the winter 1979-80 to determine effects of freeze irrigation on the Floridan aquifer. Additional data from regional observation wells were used to construct potentiometric maps comparing freeze to non-freeze conditions. Hydrographs were prepared showing water level fluctuations during freezes in winters 1977-80 at two wells with continuous water level recorders. Pumping rates were determined from flowmeter measurements and published data.

In protecting the area's 600 acres of ferns during a freeze, 8 inch irrigation wells, each producing 1500 gpm, extract up to 170 mgd of water from the Floridan aquifer. Cold fronts preceded freezes on February 1-5 and March 2-4, 1980 with maximum drawdowns of 11.4 and 18.6 feet occurring in March at the study sites after 20 hours of pumping. Potentiometric maps show pumping influence diminishes greatly with distance from growing centers and hydrographs indicate water levels recover to near pre-freeze conditions within a day. Previous years' hydrographs reveal increasing drawdowns during successive freezes, suggesting greater regional ground water withdrawal.

Chemical analyses of all samples collected before and during the February 1980 freeze are similar indicating no significant changes in water quality taking place.

ACKNOWLEDGEMENTS

I would like to express my appreciation for the cooperation extended by the managers of Wesley Morris and Sons, Inc., Forest Groves, Inc., and Eurotropic Corporation.

This research was conducted with the viewpoint that investigation of ground water is in the best interest of those depending on it most. It is sincerely hoped that knowledge gained from this and future efforts will lead to a program of continued wise and profitable use of the water resources in the Crescent City area.

INTRODUCTION

BACKGROUND

The aquifer system in Southeast Putnam County, Florida forms a potentiometric high, yielding substantial quantities of fresh water for local agricultural and domestic use. An expanding 600-acre fern industry, contributing four million dollars annually to the local economy, is the area's largest user of ground water (Tilton, A., 1980, Personal Communication). Ferns grow abundantly in the region's well-drained sandy soils but require some method of irrigation to maintain optimum soil moisture for maximum growth and to protect delicate ferns from freezing after the passage of a cold front.

A typical fernery irrigation system consists of an 8 inch or greater diameter well equipped with a large capacity centrifugal or turbine pump capable of withdrawing 1,500 gallons per minute (gpm) or more. Pumped water delivered to "rain bird" sprinklers is distributed at a rate of 200 gpm per acre, requiring one large well for approximately each 7 1/2 acres of ferns. Largest continuous withdrawals of irrigation water occur during hard freezes when pumps, running a day's length or longer, may extract more than 170 million gallons per day (mgd) to protect the area's 600 acres of ferns. Larger fern-growing facilities of 20 acres or greater operate with three or more high capacity wells. Most larger facilities are concentrated in two areas, one within 2 miles of Crescent City, the other in the Lake Margarett area near Fruitland (Figure 1).

Intensive ground water withdrawals may cause problems such as salt water intrusion, temporary losses of water to domestic wells, and increased sinkhole activity. In the highly developed fern-growing area near Pierson,

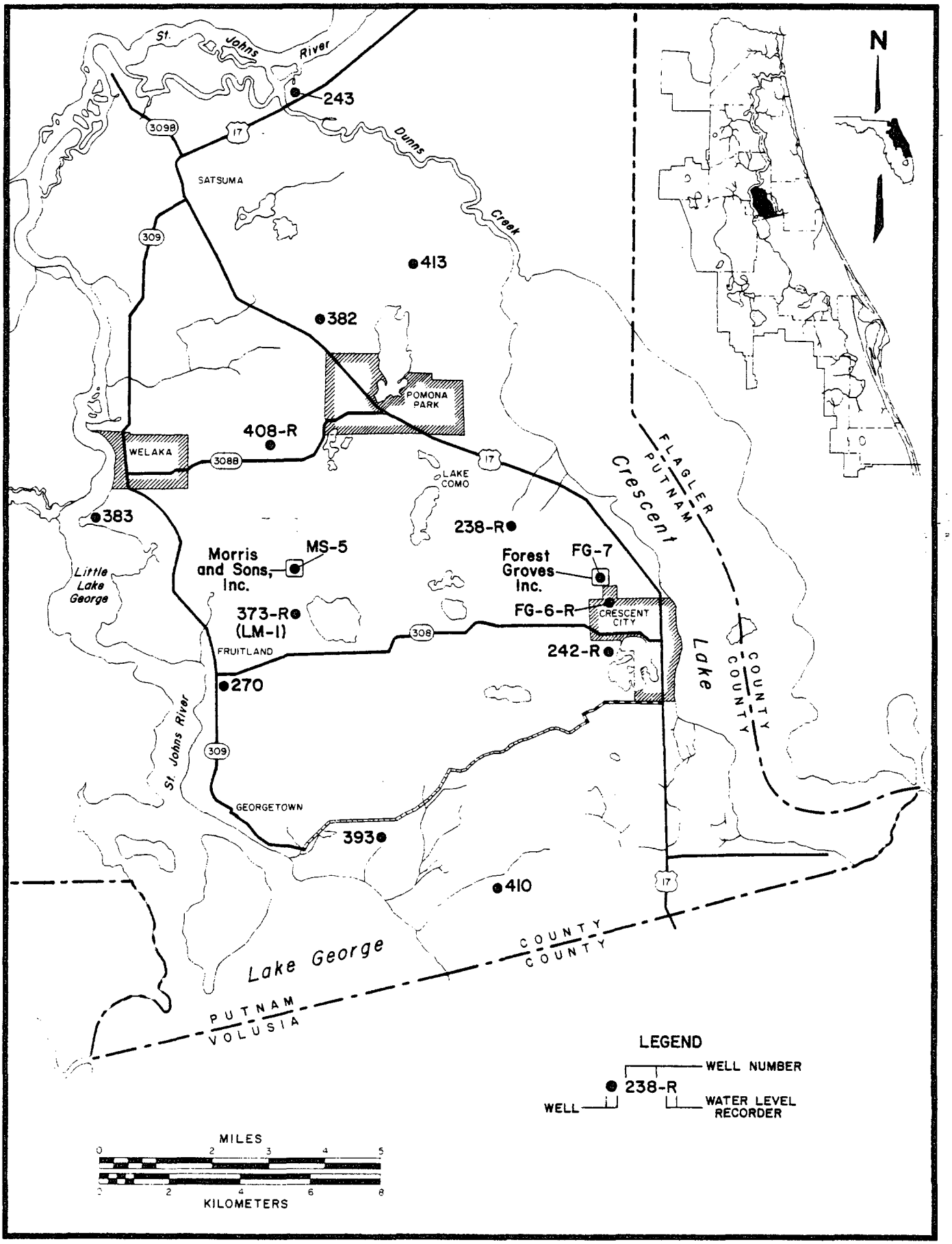


FIGURE 1. -- Map of Crescent City Ridge Area Showing Locations of Fernery Study Sites and "Key" Regional Observation Wells

Volusia County, closely spaced irrigation systems cause occurrences of similar problems; and in Southeast Putnam County, intensive pumping lowers the potentiometric surface below the pump intakes in some domestic wells. A previous study of the Crescent City Ridge area (Ross and Munch, 1980) indicates a need for data relating drawdowns to possible changes in water quality occurring in the Floridan aquifer.

FREEZE PROTECTION

Typically, after passage of a winter cold front, skies clear, and air turns cold and dry. At such times, all solid objects on earth radiate heat energy into space at approximately 0.1 calorie per square centimeter per minute or one million BTU's per acre per hour (Mee, 1977, p. 204). A similar continuous loss of heat energy from unprotected ferns results in plant tissue damage.

Heat energy stored in ground water is used to protect ferns from cold weather. Water releases 80 calories per gram (latent heat of fusion) accompanying the change in state to a solid in addition to heat produced as the temperature of applied ground water falls from 72° F to freezing. An application rate of .35 inch per hour releases approximately 11,400 BTU per acre, however, a continuous fresh film of water must be uniformly applied to plants, otherwise greater damage occurs than if sprinkler systems are not used. Unfortunately, applications of large amounts of water necessary for preventing freeze damage also leaches nutrients from soil, damages soil structure, and may cause root and rhizome damage (Harrison and Conover, 1970, p. 4 and 5).

PURPOSE AND SCOPE

The author became acquainted with fernery irrigation methods while conducting research on the hydrologic investigation of the Crescent City Potentiometric high. Hydrographs from observation wells monitoring the Floridan aquifer showed temporary reductions in water levels from intensified ground water withdrawals for fernery freeze protection. Documenting the regional and local hydrologic effects of freeze protection went beyond the scope of the initial investigation. However, in light of complaints of local citizens regarding failing domestic wells coincident with freezing weather, and problems observed in the fern-growing areas of Volusia County, drawdowns and water use accompanying freeze protection warranted further investigation.

Effects of freeze protection on the Floridan aquifer in Southeast Putnam County were studied emphasizing monitoring chemical and physical changes occurring within the aquifer. Research conducted at two large ferneries, facilitated data collection while allowing for extrapolation over broader areas on the Crescent City Ridge.

METHODS OF INVESTIGATION

Two large ferneries were selected for study, each considered representative of their respective area of production; one located approximately 2 miles northeast of Fruitland, the other less than 1 mile north of Crescent City (Figure 1).

The District drilled a deep Floridan aquifer monitor well at each of the ferneries in locations suitable for determining maximum local effects of freeze pumping on the aquifer. Continuous digital water level recorders

were installed on four existing wells open to the Floridan aquifer, one at the fernery near Crescent City, and three at the fernery near Fruitland (Figures 2 and 3). Elevations of measuring points were established at new water level observation wells for continued referencing of all data in the region to mean sea level. Hydrographs depicting freeze-drawdowns at wells with continuous water level recorders were compared to historical freeze data (1977-79) from three regional observation wells. Water levels measured at "key" monitor wells (Figure 1) contributed data for constructing maps of the Crescent City Ridge area depicting potentiometric levels before and after a major freeze.

Water samples collected for chemical analyses from production and observation wells prior to the winter pumping season provided baseline water quality. Water quality parameters consisted of sulfate, chloride, sodium, magnesium, potassium, calcium, and total dissolved iron concentrations. Wells sampled twice during a severe freeze documented changes in water quality.

Geophysical logs established total depth, geologic formations penetrated, and producing zones associated with each well. A flowmeter, installed at the outflow of a major producing well in the fernery near Fruitland, provided withdrawal measurements establishing well production capabilities and estimated water use for normal as well as freeze protection irrigation periods.

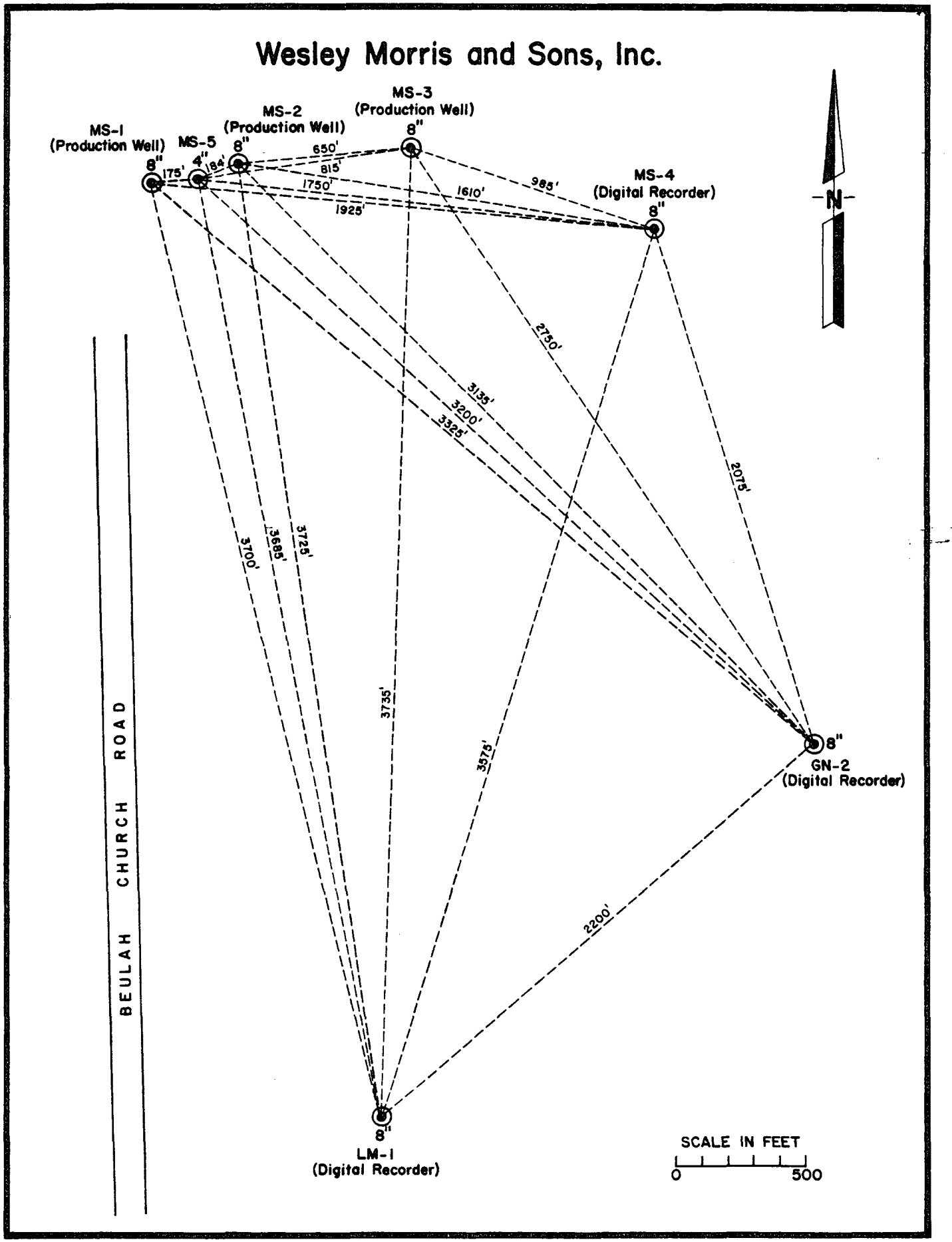


FIGURE 2. -- Map Showing Locations and Distances Between Production and Observation Wells at Wesley Morris and Sons, Inc.

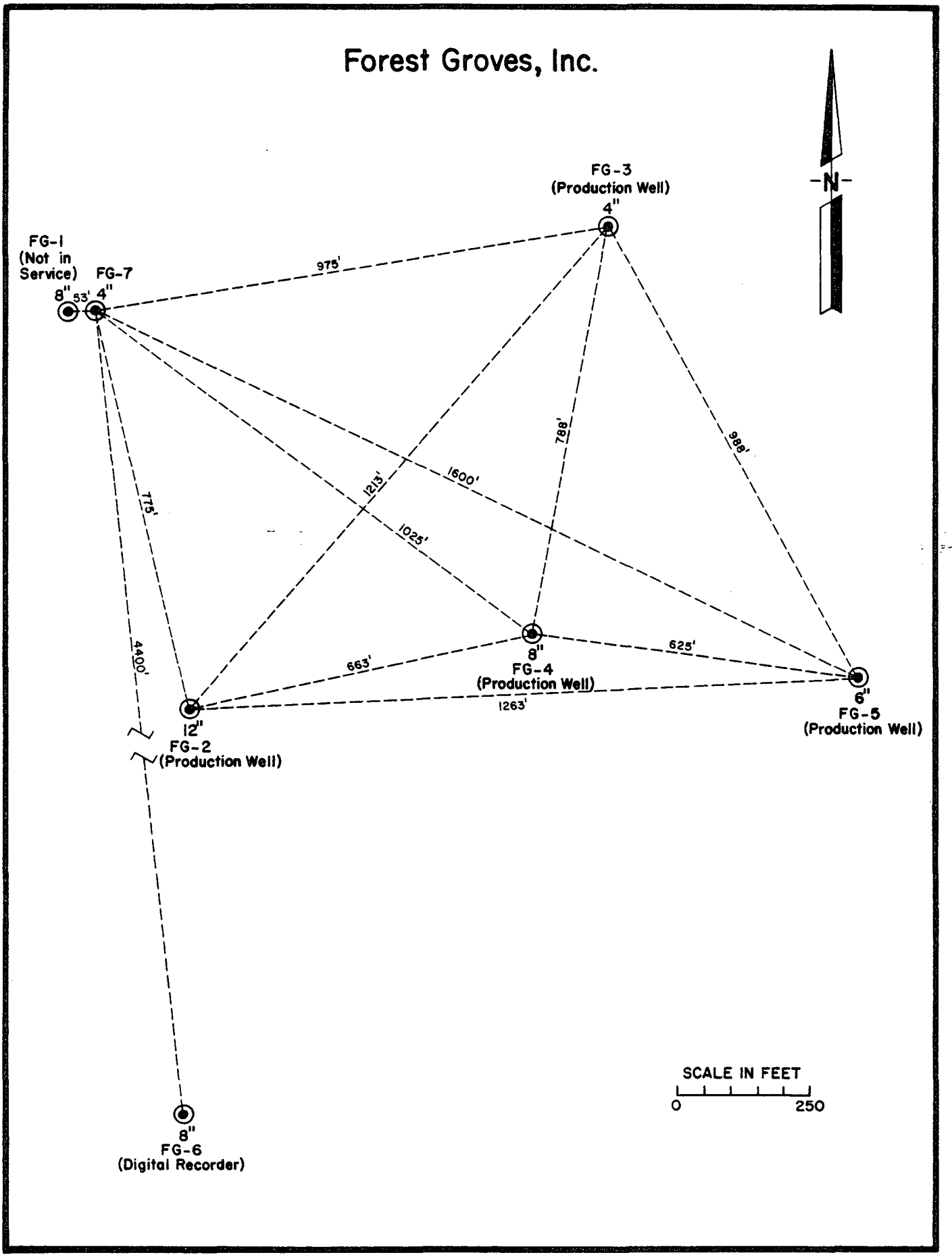


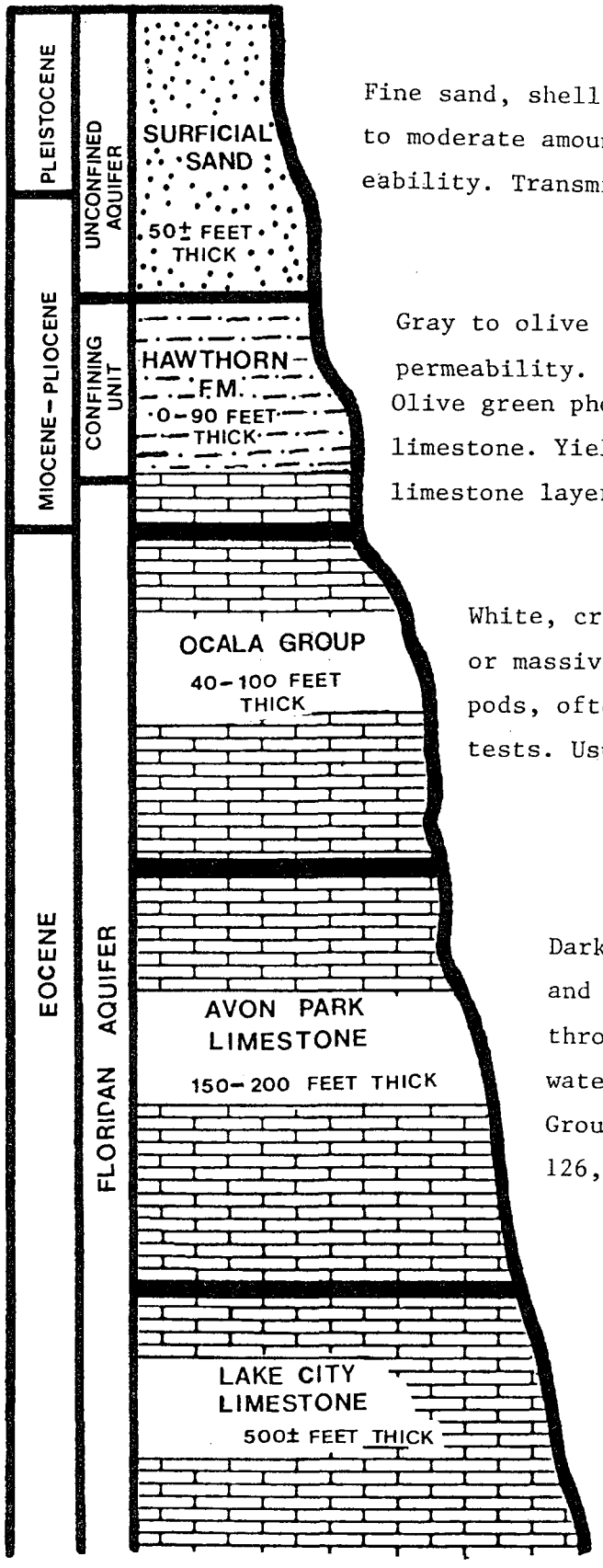
FIGURE 3. -- Map Showing Locations and Distances Between Production and Observation Wells at Forest Groves, Inc.

HYDROGEOLOGY

The area of hills, lakes, and marshes occupying Southeast Putnam County is known as the Crescent City Ridge. Limestones of Eocene Age (Lake City Limestone, Avon Park Limestone, and the Ocala Group) form an elongated high structurally supporting the Ridge. The Hawthorn Formation, consisting of Middle Miocene hard green clay with lenses of phosphatic clay, sands, limestones, and coquina, lies unconformably upon the Ocala Group (Bermes, Leve, and Tarver, 1963, p. 20). Approximately 50 feet of unconsolidated, well sorted, fine to very fine surficial sands and clayey sands rest atop the Hawthorn Formation, forming relict beach ridges deposited during the 100-foot rise in sea level (Pirkle, Yoho, and Hendry, 1970, p. 32). The geologic column (Figure 4) shows the hydrologically significant rock units of southeast Putnam County. Geophysical logs of fernery observation wells are presented in Appendix A.

The ground water system in the Crescent City Ridge area consists of non-artesian, secondary artesian, and artesian aquifers. The non-artesian (unconfined) aquifer is composed of the fine grained sands and clayey sands of the surficial deposits. The water table conforms to the topography, lying near the surface in low areas, and rising to within a few tens of feet below the crests of the prominent sand hills.

The phosphatic clays and sandy clays of the Hawthorn Formation compose the confining unit in the area. In most of the southern portion of the Crescent City Ridge the Hawthorn Formation is replaced by equivalent or younger sediments of similar appearance, however, in the extreme southern portion, surficial sediments lie directly above the Ocala Group. Occasionally encountered within the confining unit, are secondary artesian aquifers of highly permeable, discontinous beds of coquina and limestone.



Fine sand, shell, and clayey sand. Yields small to moderate amounts of water depending on permeability. Transmissivity 10,000 to 7,500 gal/day/ft

Gray to olive green sandy clay and clay. Low permeability.
Olive green phosphatic clay with layers of shell limestone. Yields water locally from shell and limestone layers.

White, cream, tan limestone. Chalky, granular, or massive. Fossiliferous, with many Pelecypods, often composed wholly of foraminifera tests. Usually yields large amounts of water.

Dark tan to brown, hard, dense, limestone and dolomite. Many thin organic layers throughout. Yields large amounts of water. Combined transmissivity of Ocala Group and Avon Park Limestone equals 126,000 gal/day/ft.

White to dark brown interbedded limestone and dolomite. Peat bed marks top of contact with Avon Park Limestone. Yields water high in dissolved solids.

FIGURE 4. -- Idealized Geologic Section of Hydrologically Significant Rock Units Under the Crescent City Ridge

Eocene limestone and basal limestones of the Hawthorn Formation compose the artesian aquifer (Floridan aquifer), the major source of the area's fresh water. Most large irrigation wells penetrate the Avon Park Limestone while smaller irrigation wells and domestic wells draw water from the overlying Ocala Group. The deeper Lake City Limestone, not normally utilized in this area, yields water high in dissolved solids.

Potentiometric pressures within the Floridan aquifer form a localized high with water level elevations ranging from 5 to 38 feet above mean sea level (MSL). Recharge to the Floridan aquifer occurs by infiltration of precipitation through sand hills. Water moves laterally from higher to lower potentiometric levels, discharging at the ridge margins where potentiometric levels are higher than the water table (Figure 5).

Water levels in all aquifers fluctuate seasonally with lowest levels usually occurring in May and highest in September. The transmissivity of the Floridan aquifer in the Crescent City Ridge is 126,000 gal/day/ft with a coefficient of storage of 3.5×10^{-4} (Ross and Munch, 1980, p.46).

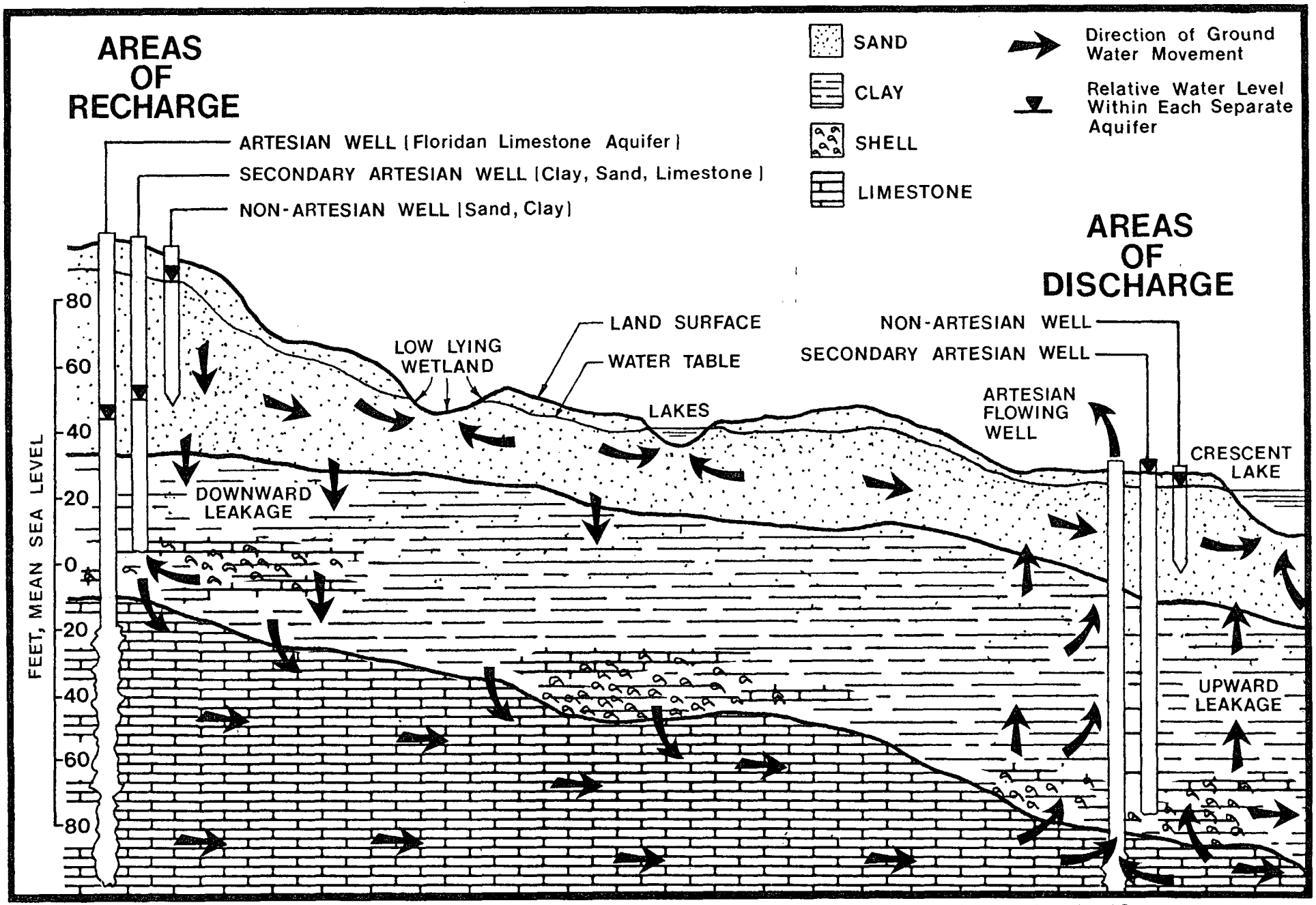


FIGURE 5. -- Diagram Showing Relationship Between Non-Artesian, Secondary Artesian, and Artesian Aquifers on the Crescent City Ridge

AREAS OF INVESTIGATION

WESLEY MORRIS AND SONS, INC.

The fernery owned and operated by Wesley Morris and Sons, Inc. is located approximately 2 miles northeast of Fruitland (Figure 1). The major portion of the operation consists of approximately 18 acres of fern mostly grown under natural oak hammock shade, and irrigated by three 8 inch wells (Figure 2). The wells are cased with iron to approximately 95 feet below land surface or roughly midway in the Hawthorn Formation, with minimum 8 inch open hole extenting down to about 200 feet, and terminating in the upper portion of the Avon Park Limestone. Each well is drawn by a diesel-powered, horizontally-driven turbine pump. The flowmeter installed on production well M.S.-1 indicates an 8 inch diameter well equipped as above yields approximately 1,500 gallons per minute, or approximately one million gallons during an average overnight freeze.

Two observation wells are located within the fernery (Figure 2). One (M.S.-5), drilled by the District, is 187 feet deep. The first 97 feet consists of 4 inch inside diameter black iron casing grouted from the top of the basal limestone of the Hawthorn Formation to the surface. Ninety feet of minimum 4 inch hole completes the well in the lower portion of the Ocala Group Limestone. The well was used to obtain periodic water levels and water samples before and during a major freeze event. The second observation well (M.S.-4), drilled by private driller, is planned for addition to the present irrigation system. This well is 8 inches in diameter, 205 feet deep and cased to 90 feet. It was used to continuously monitor water levels through the duration of the study.

Two additional wells, continuously monitoring drawdowns, are located outside the Morris' fernery (Figure 2). Both are non-operational, 8 inch diameter irrigation wells of similar construction to those described above. One well (G.N.-2) is located about 1/2 mile south of Morris and Sons, Inc. in the adjacent fernery owned by Eurotropic Corporation, with the second (L.M.-1) owned by Lee Mansfield, located about 2/3 mile south of Morris and Sons, Inc. Geophysical logs for the four observation wells are presented in Appendix A.

FOREST GROVES, INC.

The fernery owned and operated by Forest Groves, Inc., located less than 1 mile north of the city limits of Crescent City, occupies a portion of the east side of a prominent sand ridge (Figure 1). The fernery consists of approximately 30 acres grown under natural shade and interspersed with citrus.

Four large production wells (Figure 3), two 8 inches in diameter (F.G.-3 and F.G-4), one 6 inches in diameter (F.G.-5), and one 12 inches in diameter (F.G.-2) irrigate the fernery. The wells are considerably deeper than those drilled near Fruitland with reported depths of from 350 to 400 feet. Well construction consists of approximately 80 feet of iron casing terminating at the top of the Ocala Group Limestone, with open hole to completion in the Avon Park Limestone. Horizontally driven turbines pumps, powered by 30 to 100 horsepower diesel engines, are connected by a common distribution system capable of applying irrigation water at a rate of 200 gpm per acre.

One observation well (F.G.-7) was drilled by the District within the fernery (Figure 3). The well, drilled to 250 feet, consists of 80 feet of 4 inch inside diameter iron casing, with open hole from the base of the

Hawthorn Formation to its completion in the Avon Park Limestone. The well was used to obtain periodic water levels before and during a major freeze. A second observation well (F.G.-6), located approximately 1 mile south of Forest Groves, Inc., provided continuous drawdown data. Drilled by private driller for eventual use in irrigation, the well is 8 inches in diameter, cased to 94 feet, and completed in the Avon Park Limestone to a depth of 360 feet. Geophysical logs for observation wells F.G.-7 and F.G.-6 are presented in Appendix A.

RECORD OF FREEZE PROTECTION

Four freeze periods severe enough to require irrigation occurred during the winter of 1979-80--November 30, December 1, January 3, February 1-5, and March 2-4. The first two freeze periods occurred over a single night and morning with less than 12 hours of continuous freezing temperatures, while the latter two occurred over several days with freezing temperatures lasting more than 12 hours (Table 1). Since January 1977, when the District began monitoring water levels in the Crescent City area, meteorological data show the occurrence of four additional severe freezes in the Central Florida region. Temperatures dropped below freezing on January 3-5, 1979, January 15-17, 1978, January 10-12, 1978, and January 17-23, 1977. The freeze of January 1977 was the most severe of the past few years.

WATER LEVEL CHANGES IN THE FLORIDAN AQUIFER

Hydrographs displaying fluctuations of the potentiometric surface in observation wells with continuous water level recorders at Morris and Sons, Inc., and near Forest Groves, Inc. during the freezes of February 1-5 and March 2-4, 1980 are shown in Figure 6. The hydrographs indicate occurrences of three separate events requiring plant protection during the February freeze and two within the March freeze. Each pumping interval is marked by a steep decline in water level followed by a more gradual return to near pre-pumping levels over a modest recovery period. Variations in drawdown exhibited at a particular observation well are directly related to the duration of pumping effecting that well. Variations in drawdowns between

TABLE 1.--Cold Fronts During Winter 1979-80 With Intervals of Freezing Temperatures Defined by Hours of Continuous Irrigation

Cold Front	Time Pumps Turned On/Off	Date	Total Hrs. of Irrigation
11-30-79	2100	11-30	11.0
to			
12-1-79	0800	12-1	
1-3-80	0300	1-3	6.0
	0900	1-3	
	2000	2-1	14.0
	1000	2-2	
2-1-80			
to	1900	2-3	13.0
2-5-80	1000	2-4	
	0100	2-5	8.0
	0900	2-5	
	1500	3-2	20.0
3-2-80	1100	3-3	
to			
3-4-80	1900	3-3	13.0
	0800	3-4	

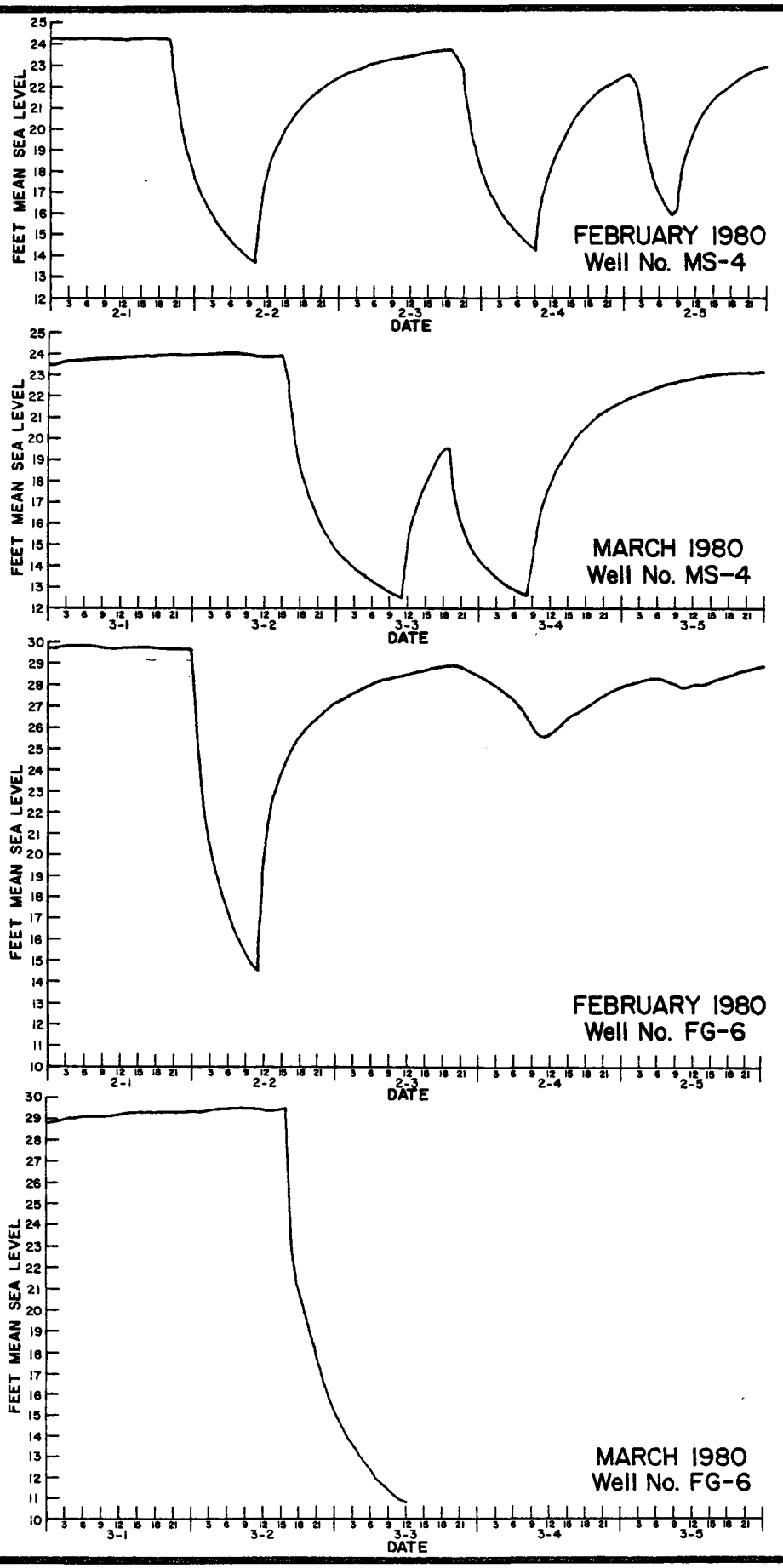


FIGURE 6. -- Hydrographs Displaying Fluctuations in the Potentiometric Surface of the Floridan Aquifer at Observation Wells MS-4 and FG-6 During Freezes of February 1-5, and March 2-4, 1980

different observation wells are directly related to volume of water removed from production wells, distance from production wells, duration of pumping, and ability of the Floridan aquifer to transmit water (transmissivity).

Greatest drawdown occurred the evening and early morning hours of March 2-4, 1980 produced by area wide pumping for approximately 20 hours from about 3:00 p.m. March 2 to about 11:00 a.m. March 3. The potentiometric surface declined from 24 to 12.6 feet above MSL, a reduction of 11.4 feet, at observation well M.S.-4 (Morris and Sons) and from 29.4 to 10.8 feet above MSL, a reduction of 18.6 feet, at observation well F.G.-6 (near Forest Groves). The hydrograph for observation well F.G.-6 ends abruptly just prior to pump shutdown because water level decline exceeded the length of steel tape attached to the float mechanism on the digital recorder. At observation well M.S.-4, a short recovery period of 8 hours, followed by an additional 13 hours of pumping on March 3 and 4, lowered the potentiometric surface to the level observe the day before. With cessation of cold weather, water levels recovered to near pre-freeze conditions.

February's freeze required three separate pumping periods of 14, 14, and 7 hours at Morris and Sons, Inc., and 11, 14, and 5 hours at Forest Groves, Inc. Pumping on February 1 and 2 lowered the potentiometric surface from 29.7 to 14.5 feet above MSL, a reduction of 15.2 feet at observation well F.G.-6 (near Forest Groves) and from 24.2 to 13.6 feet above MSL, a reduction of 10.6 feet at observation well M.S.-4 (Morris and Sons). Apparently, weather conditions on February 4 and 5 were less severe near Crescent City than at Fruitland as indicated by the considerably smaller, more gently sloping drawdowns. Drawdowns near Forest Groves reflect an overall regional response to pumping rather than the direct influence of pumping at the fernery. Freezes at Morris and Sons fernery on February 4 and 5 resulted in

drawdowns at well M.S.-4 of 10.0 and 8.4 feet from 14 hours and 5 hours of pumping respectively.

The question of how much and how long water levels could continue to decline during a long freeze at present pumping capacities remains unanswered. Although the rate of drawdown decreases with time of pumping, hydrographs (Figure 6) indicate water levels would have continued to decline had temperatures necessitated further pumping.

Hydrographs for regional observation wells 238 and 242 (Figures 7 and 8) show the most severe freeze occurring in each of the winters of 1977 through 1980. The hydrograph of well 238 for January 1977 indicates pumps ran more or less continuously for 3 days, January 17- 20, producing a maximum drawdown of 2.5 feet. In January 1979 only 36 hours of freeze pumping produced 2.65 feet of drawdown, and by March 1980, 2.7 feet of decline occurred from only 20 hours of pumpage.

Hydrographs for regional observation well 242 show an even more dramatic change in the pattern of freeze protection with drawdowns increasing by a factor of 2 1/2 since January 1977. The yearly increase in drawdown and slope suggests greater regional ground water withdrawal for the expanding acreage of ferns needing protection. Estimates indicate the amount of ferns grown in Southeast Putnam County doubled from approximately 300 acres in the mid-1970's to over 600 acres by 1980 (Tilton, A., 1980, Personal Communication).

The September 1978 potentiometric map (Figure 9) shows water levels in the Floridan aquifer before an intensive pumping period, while Figure 10 shows the potentiometric surface as it possibly appeared at pump shutdown after the March 2, 1980 freeze. The most significant changes in the potentiometric surface occurred in the fern-producing centers of Crescent City and

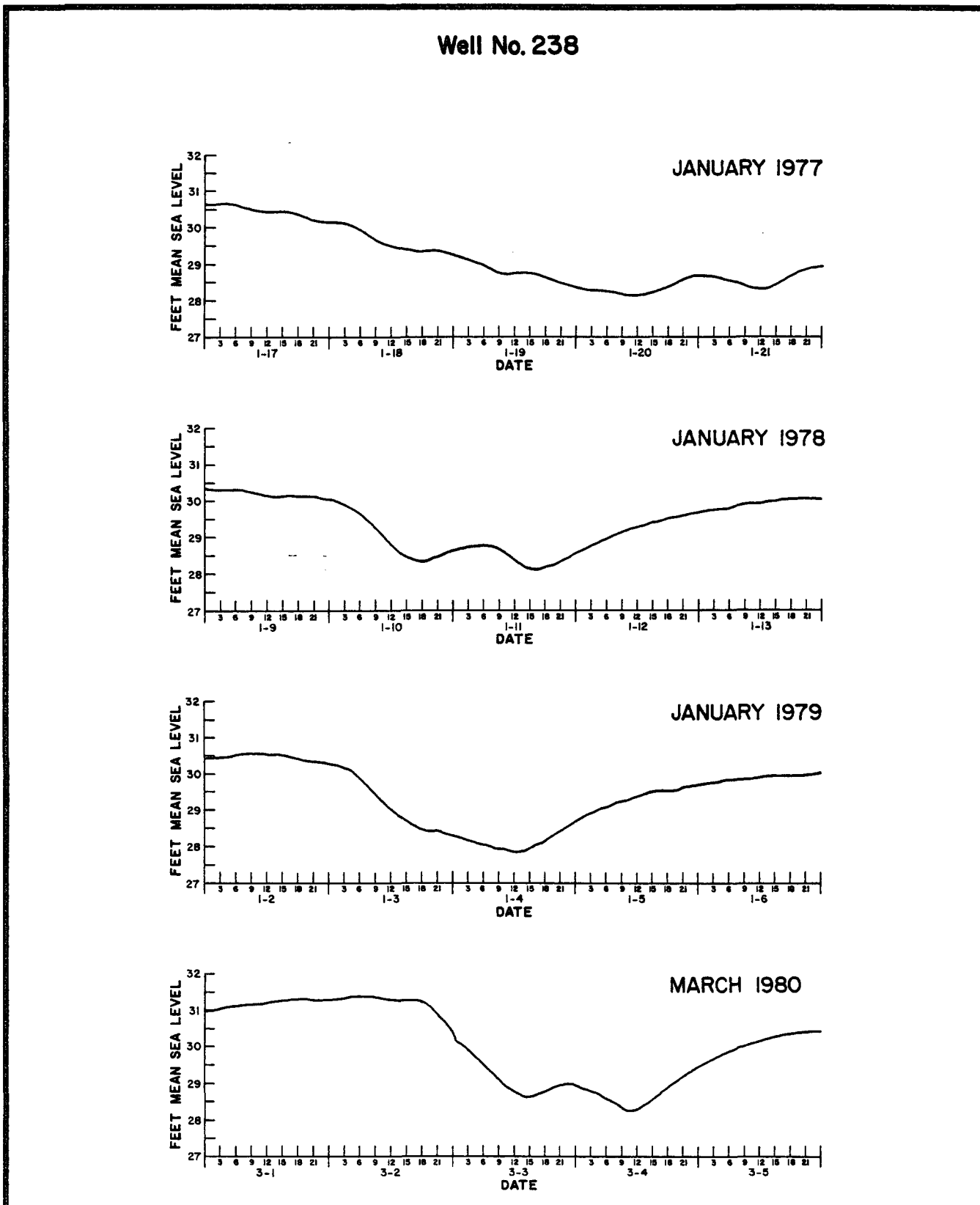


FIGURE 7. -- Hydrographs Showing Fluctuations in the Potentiometric Surface of the Floridan Aquifer at Observation Well 238 Concurrent with the Most Severe Freezes of Winters 1977-80

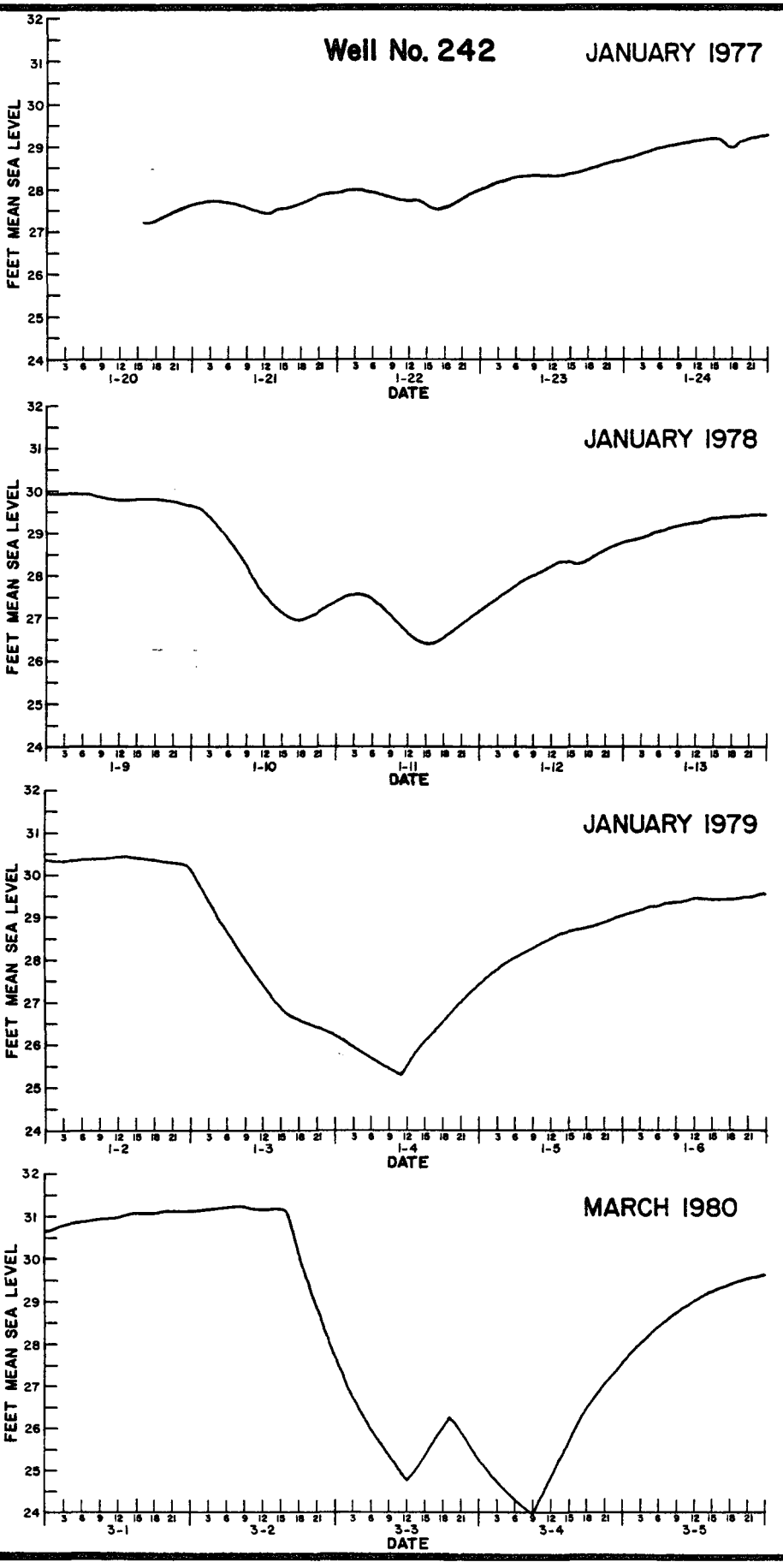


FIGURE 8. -- Hydrographs Showing Fluctuations in the Potentiometric Surface of the Floridan Aquifer at Observation Well 242 Concurrent with the Most Severe Freezes of Winters 1977-80

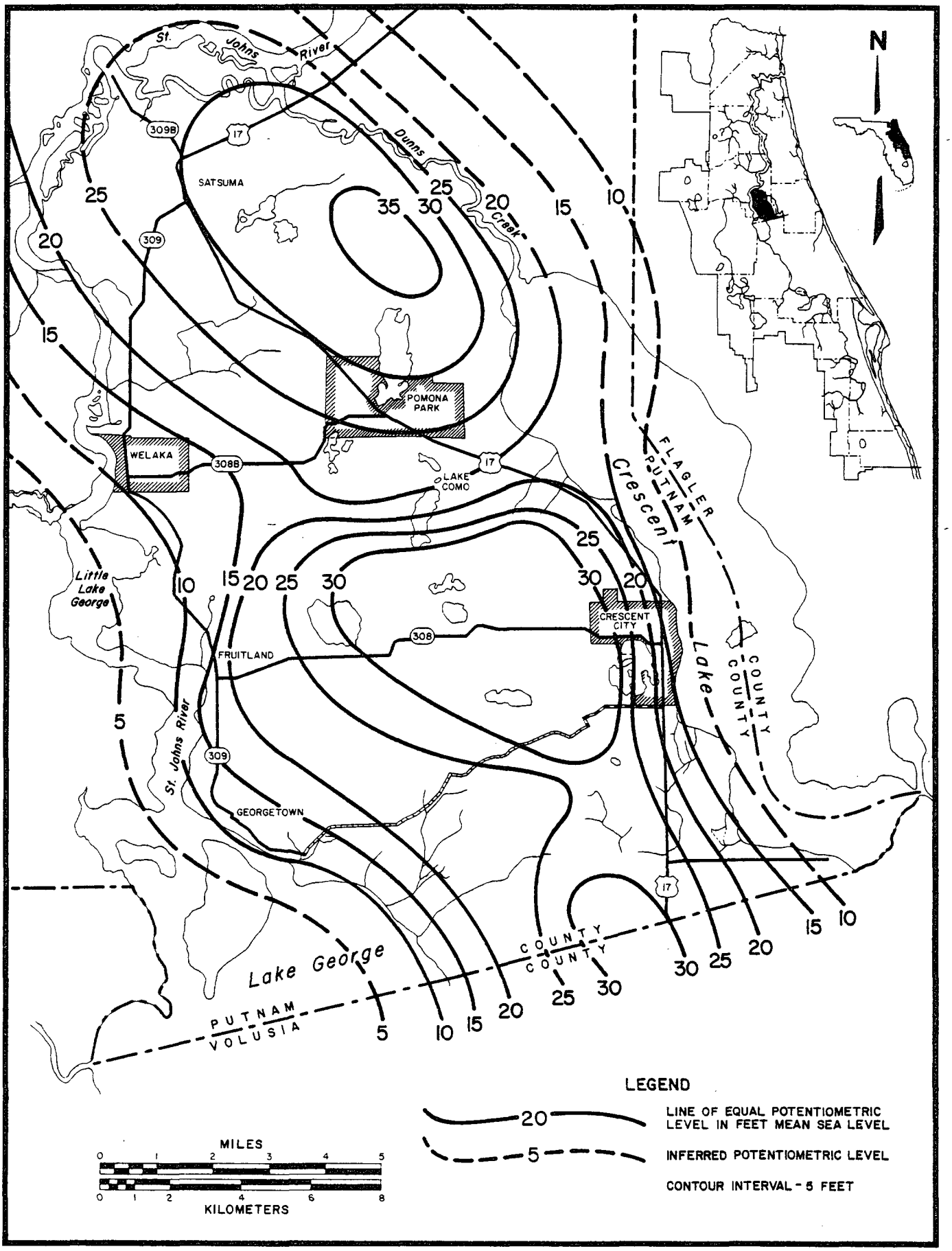


FIGURE 9. -- Map of Crescent City Ridge Showing Elevation of the Potentiometric Surface of the Floridan Aquifer for September, 1978

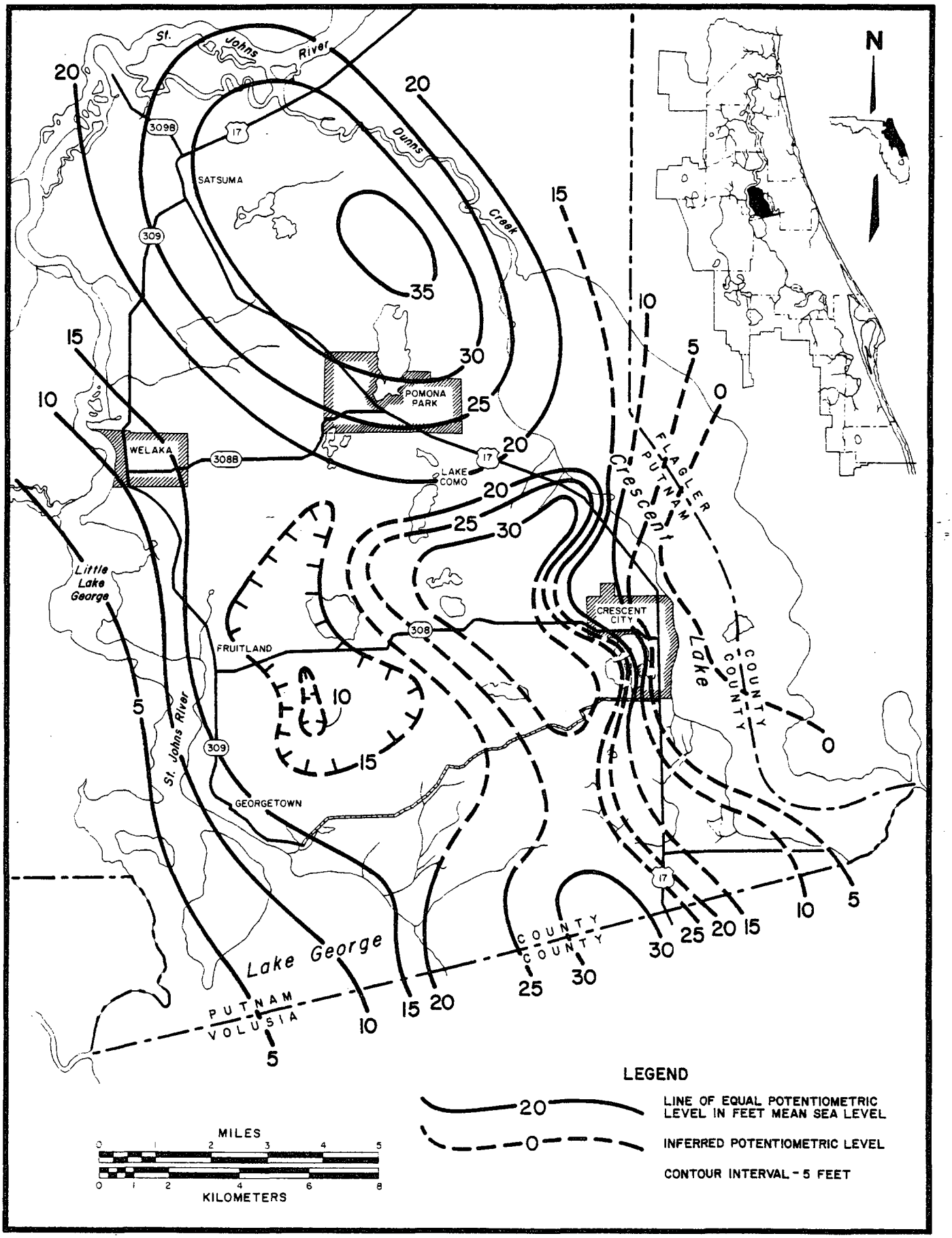


FIGURE 10. -- Map of Crescent City Ridge Depicting Elevation of the Potentiometric Surface of the Floridan Aquifer Prior to Pump Shutdown During the Freeze of March, 1980

Fruitland. During the freeze, water levels around Fruitland temporarily dropped 10 feet, from 25 to 15 feet MSL, and data suggest the area within the 30-foot contour at Crescent City diminished greatly with water levels near Forest Groves, Inc. declining approximately 15 feet. Although neighboring domestic wells may still be effected, the potentiometric maps indicate reduced influence of freeze pumpage away from fern-producing centers with negligible changes in water level occurring in many areas. Despite occasional fluctuations in water level, the limestone underlying the Crescent City ridge appears resistant to erosion and not prone to sinkhole formation.

WATER QUALITY

Broad sampling of the Floridan aquifer in the Crescent City Ridge area in 1978 records water low in dissolved solids with chloride ion concentrations less than 30 parts per million (ppm) (Ross and Munch, 1980, p. 53). Composition ratios on a Piper diagram, dominated by alkaline earths (Calcium and Magnesium) and weak acids (bicarbonate and Carbonate) typify Floridan aquifer recharge areas. However, several wells sampled near the St. Johns River contain mineralized water with chloride concentrations of 1795 to 157 ppm and composition ratios dominated by strong acids (Sulfate and Chloride) and alkali (potassium and sodium).

Nine Floridan aquifer fernery production and observation wells were sampled in December, 1979 prior to the freezes of February and March, 1980. Two of these (MS-1 and MS-5) were also sampled twice during the freeze of February 1 and 2 as well as water from a tenth production well (FG-2). Analyses of all samples are fairly uniform and consistent, comparing closely

with those of the Crescent City Ridge area from 1978. Total dissolved solids range from 130 to 247 ppm and chloride ion concentrations from 12.5 to 30 ppm (Table 2). In general, chemical data suggest no significant water quality changes occurring in the Floridan aquifer from freeze irrigation.

TABLE 2.--Water Quality Analysis Data of Samples
From Fernery Production and Observation Wells

Well No.	Date/ Time Sampled	Sodium (Na^+)	Potassium (K^+)	Calcium (Ca^{++})	Magnesium (Mg^{++})	Total Iron (Fe)	Hardness ($Ca\ Co_3$)	Total Alkilinity ($CaCo_3$)	Total Dissolved Solids	Chloride (Cl^-)	Floride (F^-)	Sulfide ($S^=$)	Sulfate ($So_4^=$)
FG-6	12-10-79	8.44	0.49	32.66	6.42	0.03	108.0	117.0	162	30.0	<.1	0.4	8.0
FG-2	2-2-80 0750	11.11	1.20	39.08	9.98	0.28	138.7	--	--	20.0	--	--	15.5
MS-1	12-12-79	5.30	0.43	24.16	4.88	0.03	80.4	101.0	130	15.0	<.1	0.6	1.3
	2-1-80 2400	5.61	0.49	23.26	4.96	0.04	78.7	--	--	12.5	--	--	3.0
	2-2-80 0700	5.61	0.46	24.96	5.13 3	0.02	83.4	--	--	12.5	--	--	3.0
MS-2	12-12-79	6.87	0.43	29.45	5.99	0.08	98.20	121.0	149	15.0	<.1	1.3	1.0
MS-4	12-10-79	11.27	0.71	35.23	7.49	0.03	118.8	159.0	185	20.0	<.1	0.4	5.1
MS-5	12-10-79	8.60	0.49	26.25	6.21	0.06	91.1	151.0	147	15.0	<.1	0.3	4.7
	2-1-80 2400	7.19	0.71	25.12	6.03	0.03	96.8	--	--	12.5	--	--	3.0
	2-2-80 0700	6.56	0.43	29.45	5.65	0.05	87.5	--	--	12.5	--	--	2.0
GN-1	12-5-79	6.40	0.37	36.51	4.02	0.70	107.7	157.5	185	12.5	<.1	0.4	3.5
GN-2	12-12-79	10.33	0.78	50.30	8.35	0.18	160.0	204.0	247	15	0.12	0.5	3.2
GN-3	12-5-79	8.60	0.43	34.59	3.59	0.85	101.1	--	165	12.5	--	0.3	3.9
LM-1	12-12-79	6.09	0.43	32.98	5.13	0.07	103.5	132.0	145	12.5	<.1	0.4	4.7

SUMMARY AND RECOMMENDATIONS

SUMMARY

Hydrographs indicate considerable fluctuation in the potentiometric surface of the Floridan aquifer from copious ground water withdrawals for fernery freeze irrigation. Freeze protection requires delivery of water at 200 gpm per acre commonly supplied by an 8 inch irrigation well for each 7 1/2 acres of crop. With each well producing 1,500 gpm, area wide ground water withdrawals for protecting 600 acres of ferns, may reach 170 mgd.

Cold fronts on February 1-5 and March 2-4, 1980 were severe enough to hold overnight temperatures below freezing for up to 20 hours. Pumping on February 1 and 2 reduced the potentiometric surface at the fern-producing center near Fruitland by 10 feet, from 25 to 15 feet above MSL. At Crescent City, the potentiometric surface was reduced by approximately 15 feet, from 30 to 15 feet above MSL. The longest freeze occurred on March 2 when 20 hours of pumping reduced the potentiometric surface to 14 feet above MSL in the immediate areas of production, a reduction of 11 feet near Fruitland and 19 feet at Crescent City. However, after cessation of pumping, water levels recovered to near pre-freeze elevations within a day. Less severe freezes result in shorter pumping periods, smaller total ground water withdrawals, reduced drawdowns, and quicker recovery periods.

Although the rate of drawdown decreases with continued pumping, hydrographs indicate descending levels up to the time of recovery (pump shut down) after as long as 20 hours of pumping. Thus, during more severe freezes, present pumping capacities may reduce water levels below those observed in

1980. Potentiometric maps of the Floridan aquifer show changes in water level diminish significantly away from centers of pumping with large areas on the Crescent City Ridge scarcely effected.

Hydrographs back to January 1977 show yearly increases in drawdown associated with freezes. Larger drawdowns with steeper slopes suggest greater regional ground water withdrawal attributed to an estimated doubling of fernery acreage since the early 1970's.

Chemical analyses of all water samples taken through the study remained consistently uniform suggesting freeze protection produced no adverse effects on water quality in the Floridan aquifer. The water, characterized as the calcium-bicarbonate type typically found in recharge areas, contains low levels of dissolved solids with chloride ion concentrations below 30 ppm.

RECOMMENDATIONS

With freezes occuring only during portions of February 2-5 and March 2-4, the winter of 1979-80 must be considered mild, and an opportunity for observing potentially extreme freeze conditions did not present itself. Since observation wells are drilled, water level recorders and flowmeter installed, and "key" area wide observation wells determined, it is recommended that a continuing program of monitoring drawdowns and water quality in the Floridan aquifer during freeze protection be established. The program should include the following elements.

1. Continued monitoring of water levels at regional observation wells and continued use of water level recorders at their present locations.

2. Collection and analysis of water samples from fernery production wells during freeze protection.

3. Remain up-to-date on installation of new ferneries and irrigation wells.

4. Cooperate with growers in establishing locations for new production wells and inform them of the importance of well placement to minimize drawdown effects.

5. Maintain lines of communication with growers and inform them of the results of our studies.

6. Maintain awareness of state-of-the-art freeze protection methods.

7. Inform local authorities, contractors, and residents of the potential for water supply problems associated with fern producing-areas. Design specifications for domestic wells taking into account water level reductions from freeze irrigation.

REFERENCES

Bermes, B. J., Leve, G. W., and Tarver, G. P., 1963, Geology and Ground Water Resources of Flagler, Putnam, and St. Johns Counties, Florida: Fla. Geological Survey Report of Investigations 32, 97 p.

Harrison, D. S., and Conover, C. A., 1970, Irrigation of Leatherleaf and Plumosus ferns: IFAS Agricultural Engineering Mimeo Report 70-7, 12 p.

Mee, T. R., 1977, Man-made Fog for Freeze Protection and Microclimatic Control; Proc. Int. Soc. Citriculture, Vol. 1, p. 203-208.

Pirkle, E. C., Yoho, W. H., and Hendry, C. W., 1970, Ancient Sea Level Stands in Florida: Fla. Bureau of Geology Bulletin 52, 61 p.

Ross, F. W., and Munch, D. A., 1980, Hydrologic Investigation of the Potentiometric High Centered About the Crescent City Ridge, Putnam County, Florida: St. Johns River Water Management District Technical Report No. 5, 75 p.

Tilton, A., 1980, Personal Communication, Putnam Co. Agricultural Agent.

APPENDIX

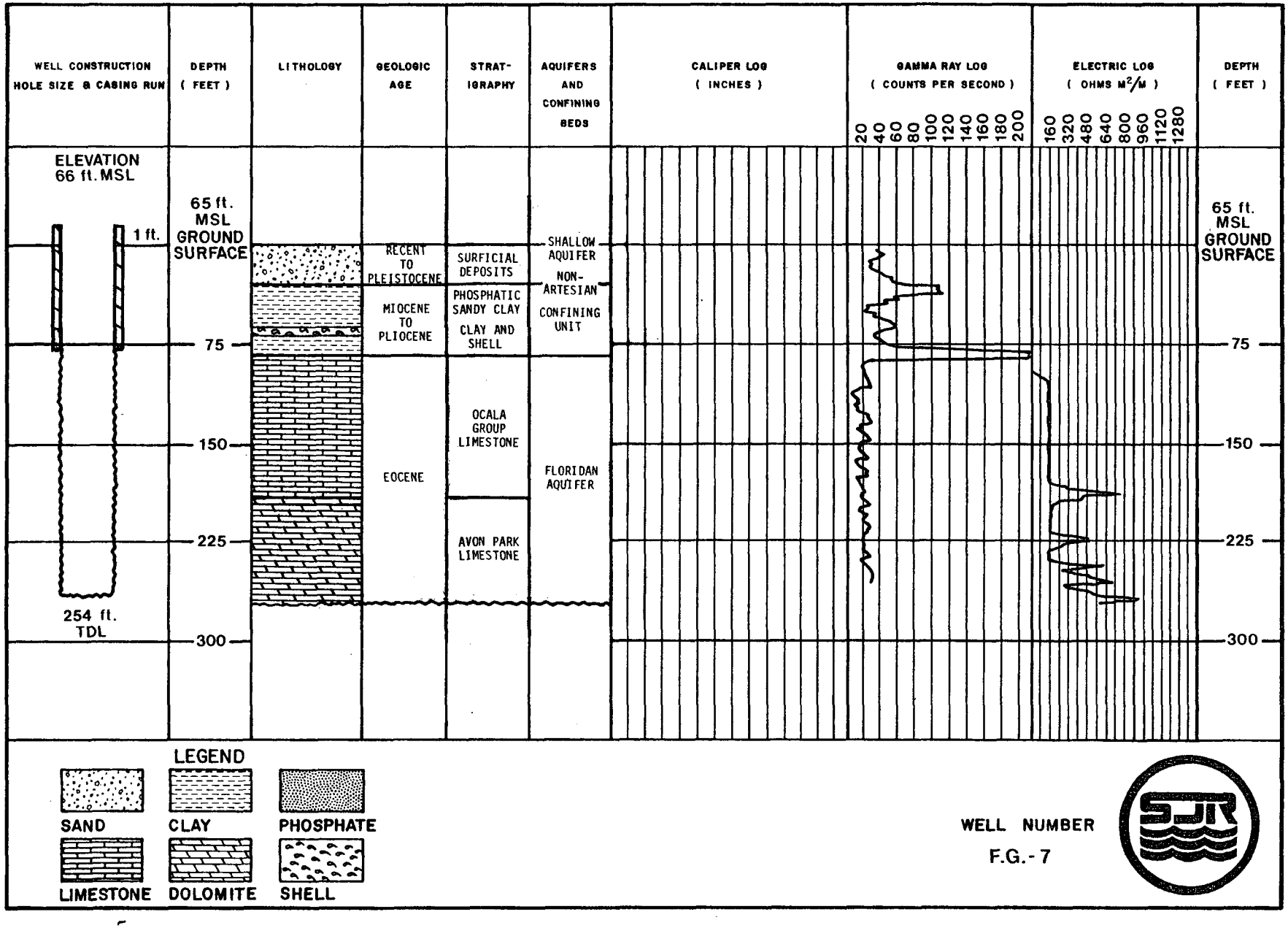


FIGURE A1. -- Hydrogeological and Geophysical Data from Observation Well FG-7

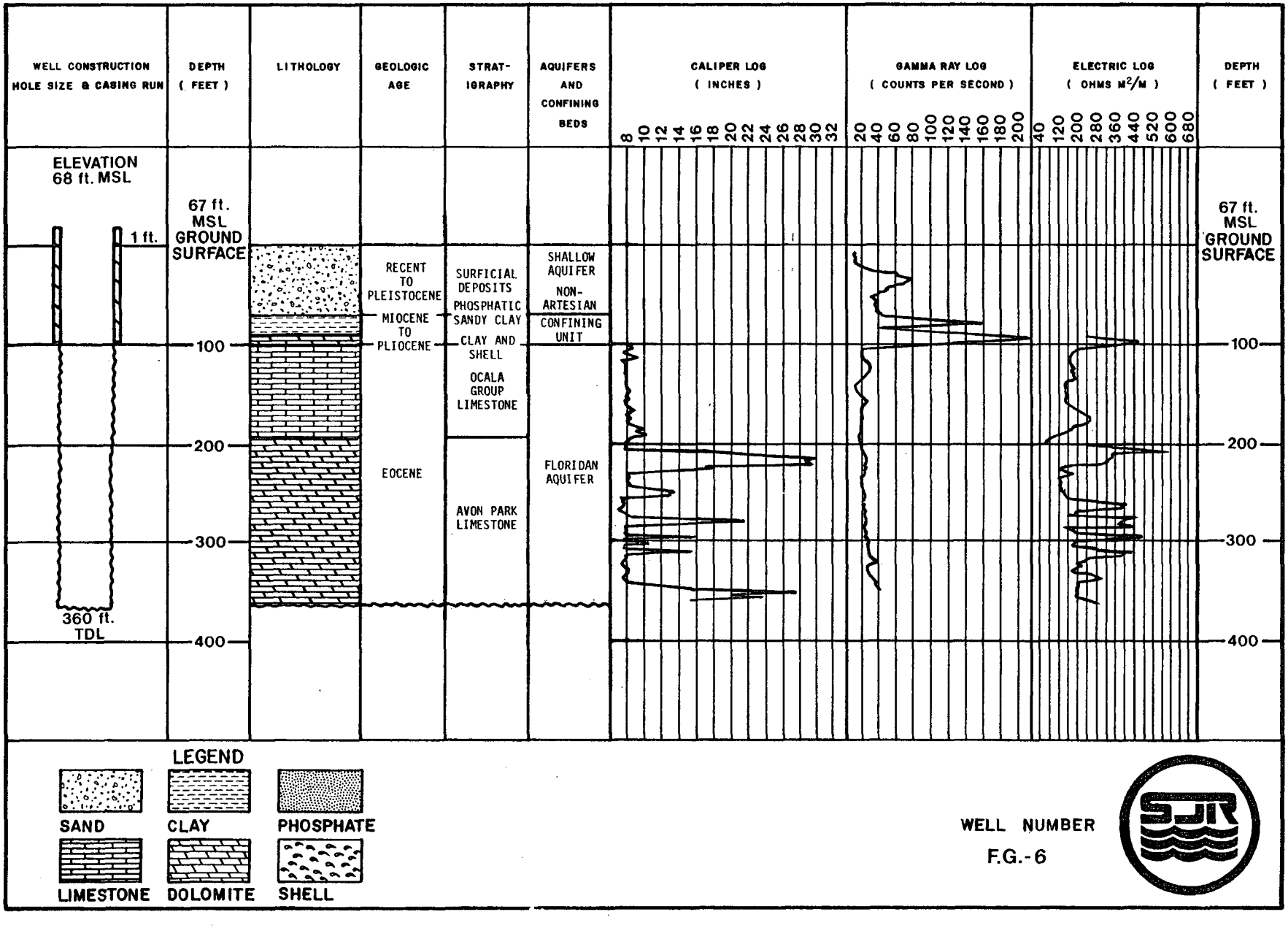


FIGURE A2. -- Hydrogeological and Geophysical Data from Observation Well FG-6

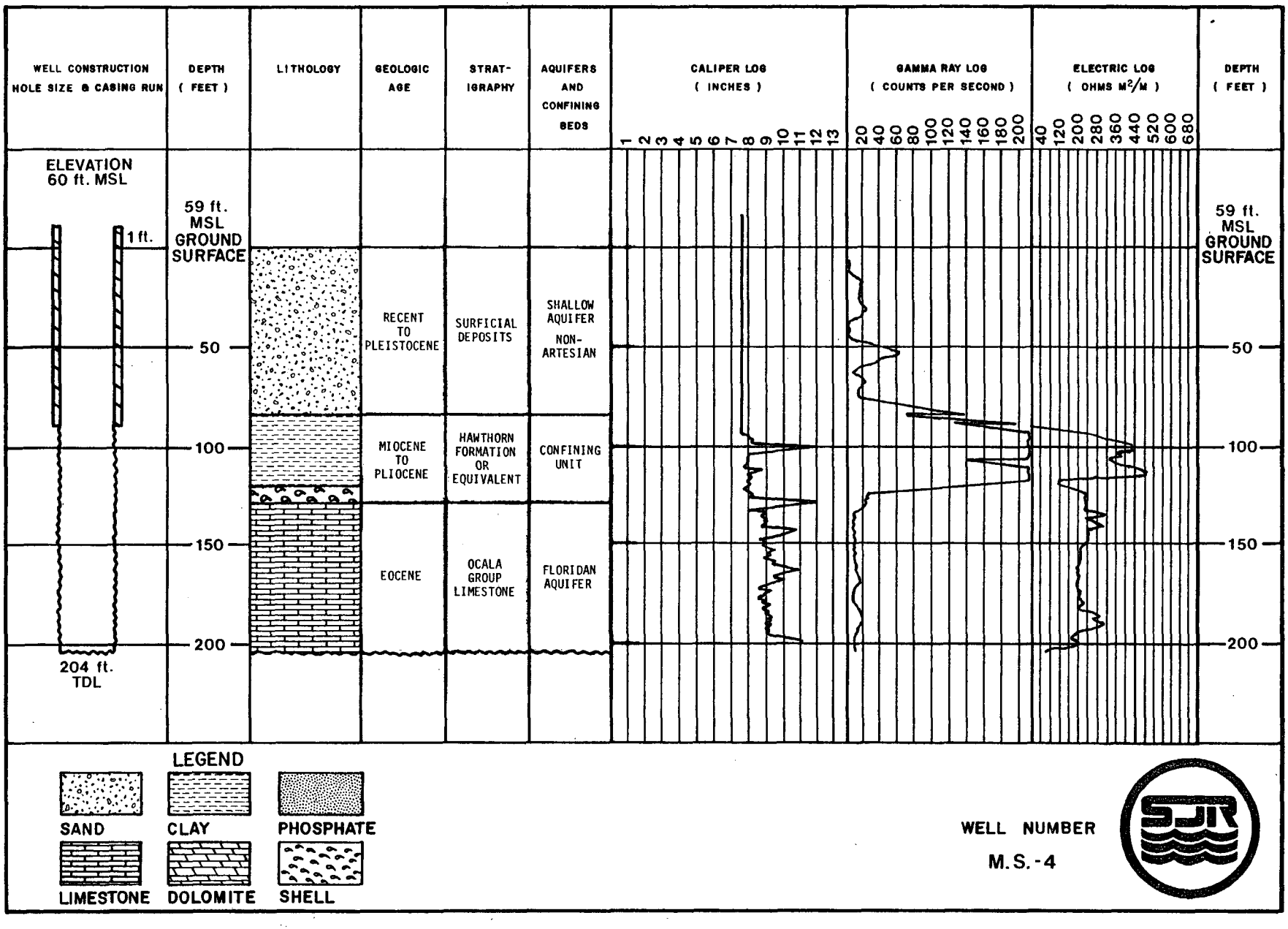


FIGURE A3. -- Hydrogeological and Geophysical Data from Observation Well MS-4

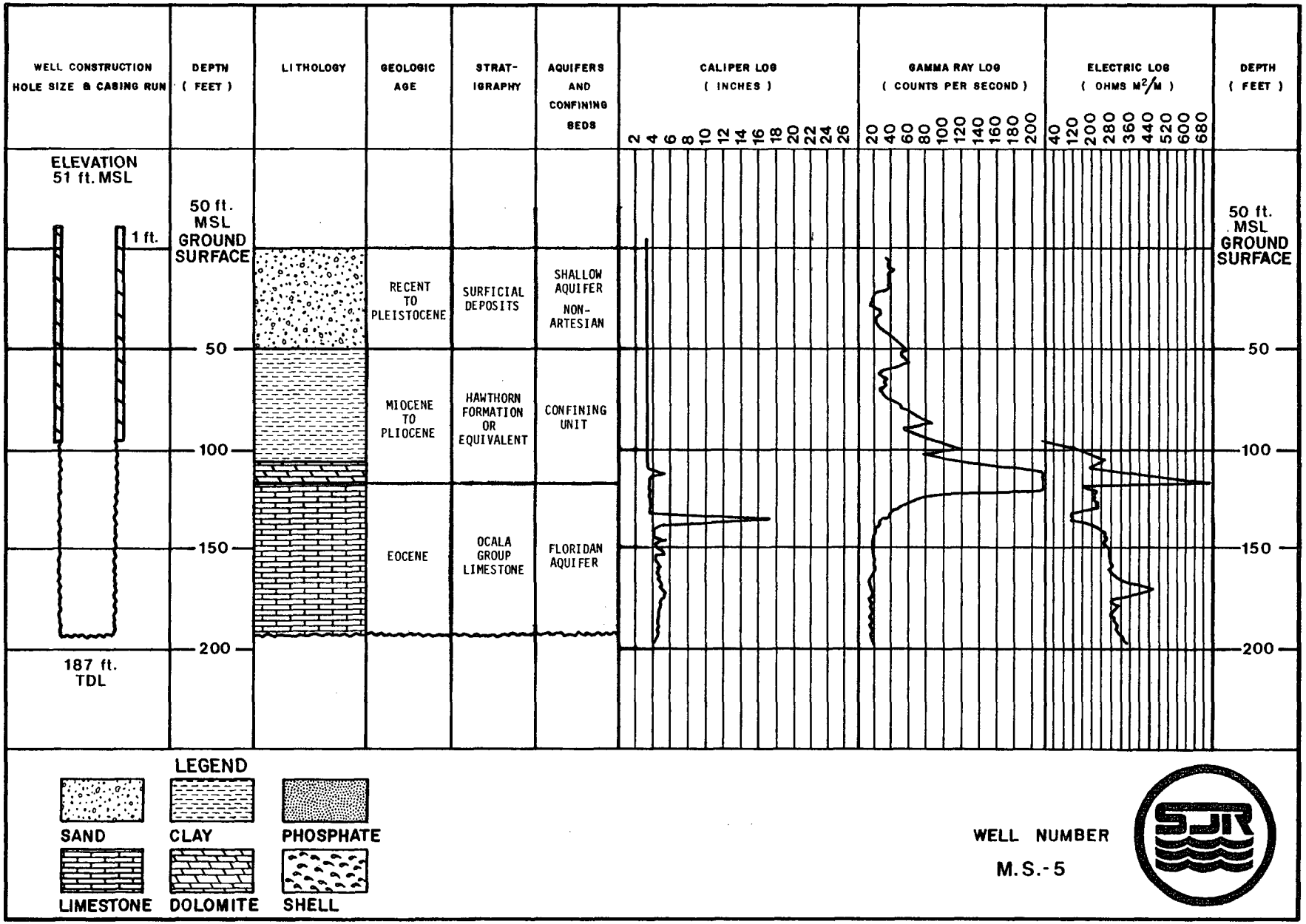


FIGURE A4. -- Hydrogeological and Geophysical Data from Observation Well MS-5

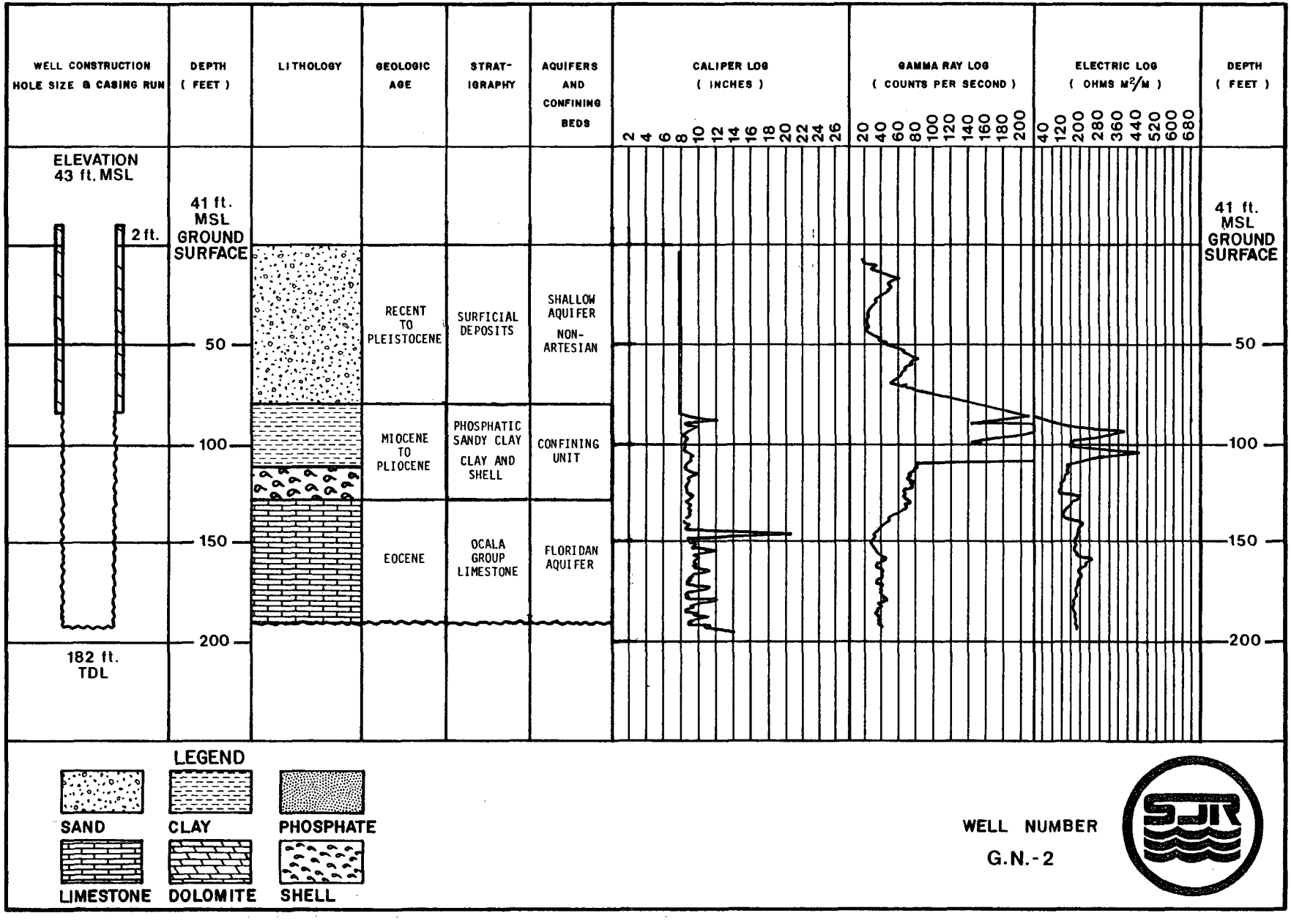


FIGURE A5. -- Hydrogeological and Geophysical Data from Observation Well GN-2

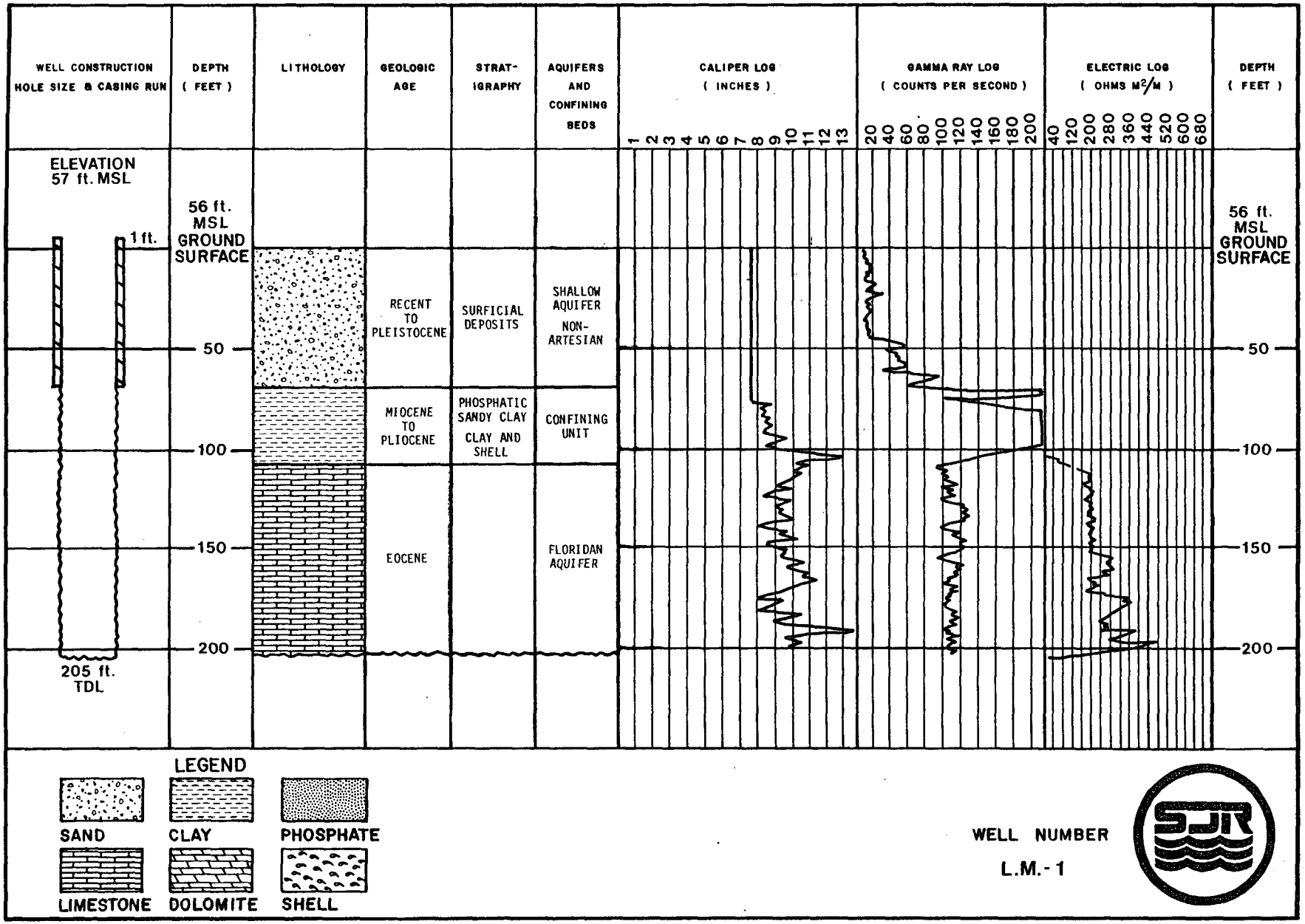


FIGURE A6. -- Hydrogeological and Geophysical Data from Observation Well LM-1