NORTH COUNTY REGIONAL WATER TREATMENT PLANT INJECTION WELL SYSTEM COMPLETION REPORT

VOLUME I - TEXT

Prepared For

Collier County Utilities Division
Water and Wastewater Services
3050 North Horseshoe Drive
Naples, Florida 33942

Prepared By The

ViroGroup
Air • Water • Soil
TECHNOLOGY

Missimer Division

NORTH COUNTY REGIONAL WATER TREATMENT PLANT INJECTION WELL SYSTEM COMPLETION REPORT

VOLUME I - TEXT

Collier County Utilities Division
Water and Wastewater Services
3050 North Horseshoe Drive
Naples, Florida 33942

August, 1993

ViroGroup, Inc./Missimer Division
428 Pine Island Road, S. W.
Cape Coral, Florida 33991

Project No.
0109342.05

Charles W. Walker, Ph.D., P.G. #1247
Senior Hydrogeologist

Lloyd E. Horvath, P.E. #26260
Vice President of Water Resources

c:\wp-rpt5\0109342.05\lk

TABLE OF CONTENTS

TABLE OF CONTENTS - Continued:

TABLE OF CONTENTS - Continued:

TABLE OF CONTENTS - Continued:

APPENDICES

LIST OF FIGURES

LIST OF FIGURES - Continued:

LIST OF TABLES

c:\wp-rpt5\0109342.05\lk

LIST OF TABLES - Continued:

1.0 INTRODUCTION

1.1 Background

This document details the drilling, construction and testing of the deep Class I injection well and dual zone monitoring well located at the Collier County Utilities Division new North County Regional Water Treatment Plant (NCRWTP). This new plant will have an initial capacity to treat 12 million gallons per day (MGD), expandable to 20 MGD. Softening membranes will be used to treat the raw water initially, but the plant is designed with the ability to convert to low pressure reverse osmosis (RO) membranes if the need arises in the future. Treatment of 12 MGD by the softening membranes will produce approximately 1.2 MGD of concentrate. At buildout, the NCRWTP will generate a maximum concentrate stream between 4.75 and 8.57 MGD, depending on the type of treatment process being used.

The completed concentrate disposal system consists of the injection well and the dual zone monitor well. Underground Injection Control (UIC) rules classify membrane process concentrate as an industrial waste which thereby requires the disposal well to be of tubing and packer design. The final depth of the injection well is 3330 feet below the construction pad level (bpl) with a final 20-inch diameter injection casing set at 2,497 feet bpl and the packer at the bottom of the 16-inch injection tubing set at 2,445 feet bpl. The injection zone, commonly referred to as the "Boulder Zone" in south Florida, is composed of highly fractured and cavernous dolomite occurring between approximately 2,560 to 3,330 feet bpl. The monitor well is designed to monitor a shallow zone occurring between 900 and 995 feet bpl and a deeper zone between 1,815 and 1,930 feet bpl. This monitoring well is located about 140 feet from the injection well.

1.2 Scope

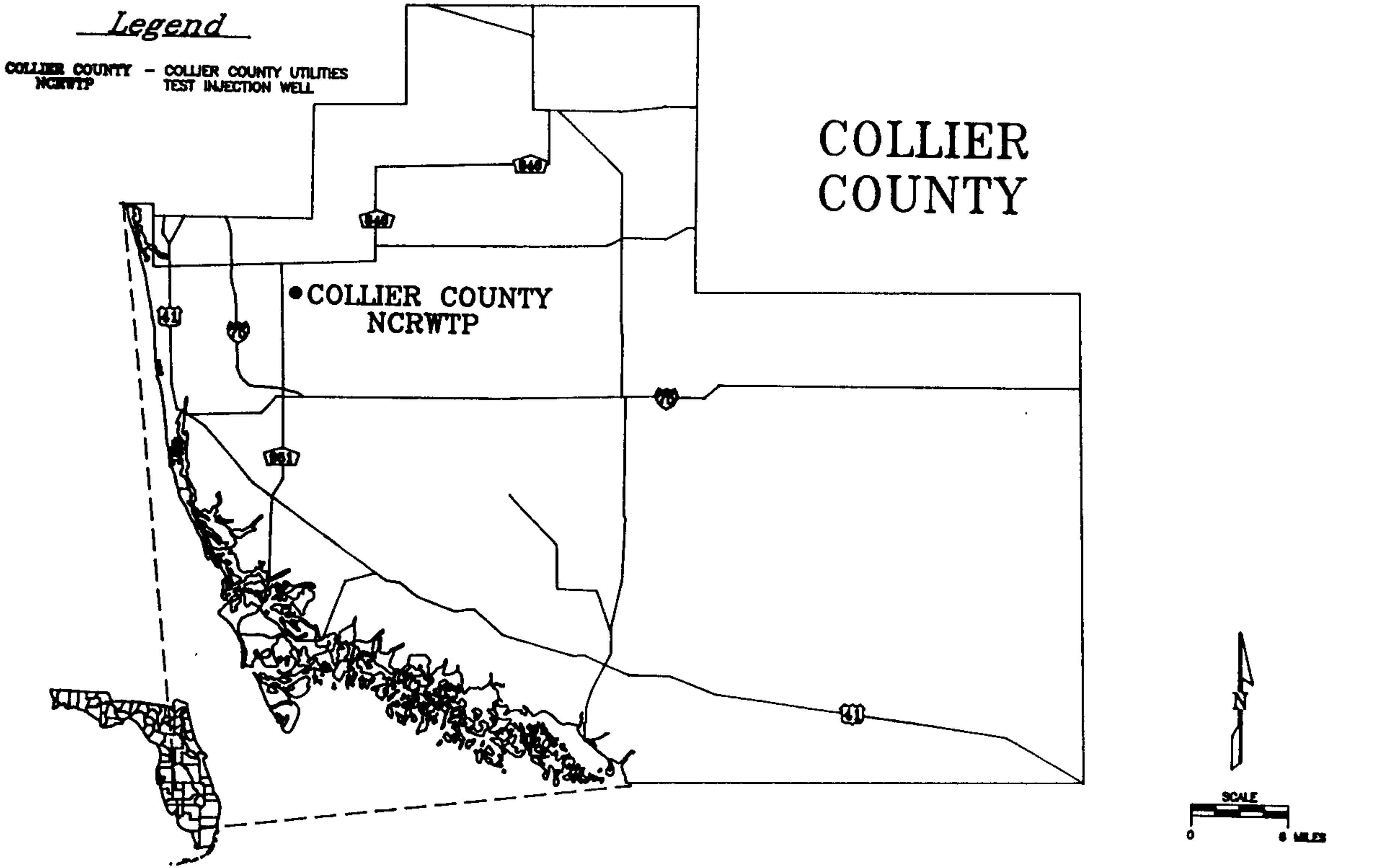
ViroGroup, Inc./Missimer Division (formerly Missimer & Associates, Inc.) was authorized in June, 1991 by the Collier County Board of Commissioners to provide consulting services for the design, permitting, construction oversight and testing of one Class I injection well system at the new North County Regional Water Treatment Plant (NCRWTP). This plant is located in the northwest Golden Gate Estates area of Collier County, Florida as shown in Figures 1 and 2. Also illustrated in Figure 2 is the "area of review" encompassing a radius of one mile around the well site in which information was obtained that revealed that no known faults and no wells penetrate the injection zone or either of the two monitor zones within this area.

The injection well (IW-1) is designed to dispose of membrane reject concentrate at a maximum rate of 6.2 mgd. Initially, emergency back-up to IW-1 will involve on-site detouring of the waste stream to a storage tank and/or the complete shut down of the water treatment plant. A second proposed well (IW-2), when constructed and permitted, will provide for 100 percent redundancy capacity.

1.3 Project Description

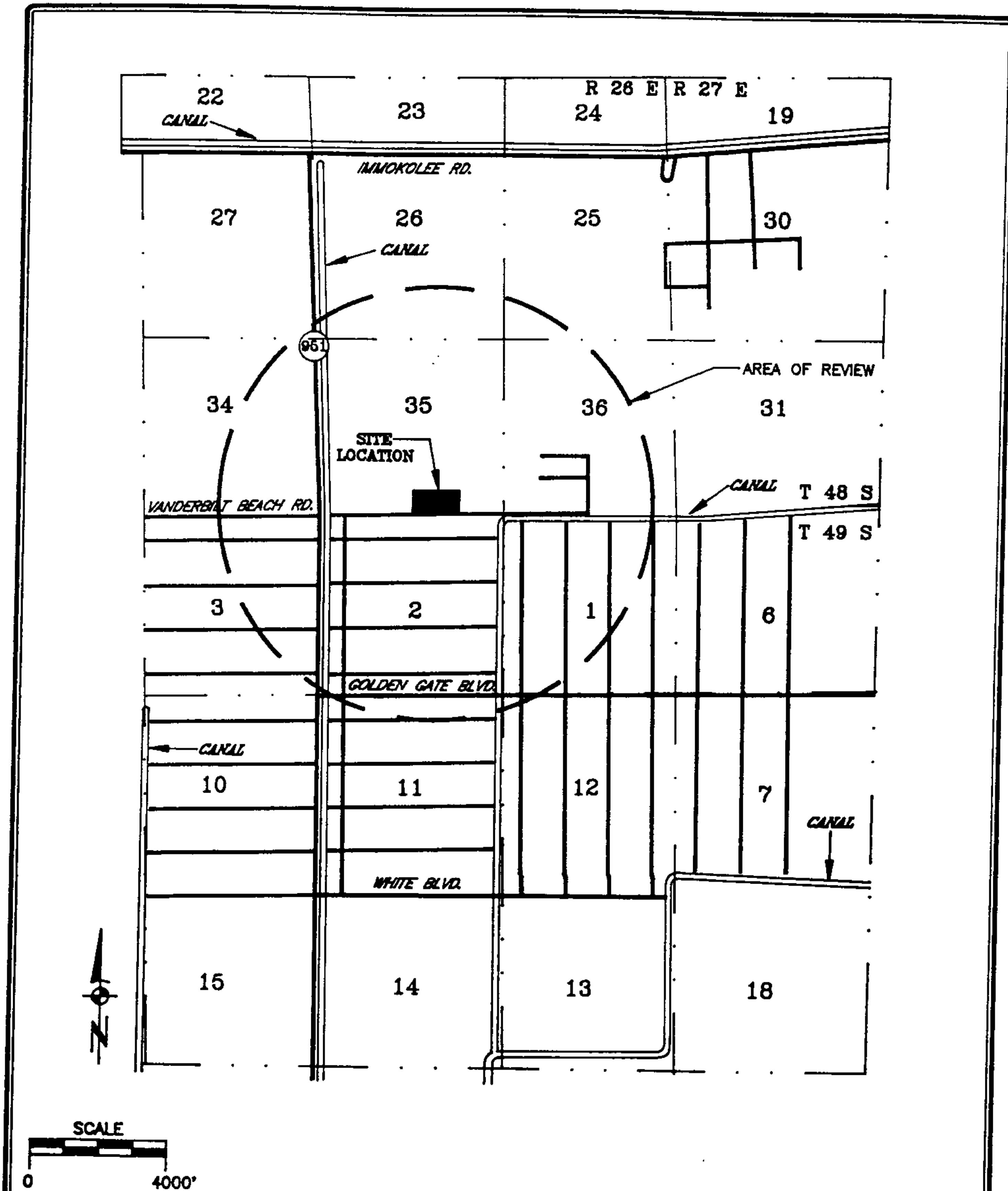
The application for the Florida Department of Environmental Protection (FDEP) Injection Well Construction permit was submitted in May, 1991. On March 18, 1992, the FDEP issued construction permit # UC11-198432 for the construction and testing of one Class I injection well and a dual-zone monitor well at the NCRWTP site. A copy of this permit and related correspondence is included in Appendix A.

Construction of IW-1 began in June of 1992. Youngquist Brothers, Inc., (sole bidder) was contracted to perform the drilling and testing services for the project. Under this contract, they were to complete two construction pads, one Class I



ViroGroup	*ENVIRONMENTAL AND GROUNDWATER SERVICES* DRN. BY: CAM DWG NO. A-019342FA-2 DATE: 4/14/93 PROJECT NAME: COLLIER COUNTY - IW-1 PROJECT NUMBER: 01-09342.00	Missimer & Associates,Inc.

FIGURE 1. COLLIER COUNTY UTILITIES NCRWTP LOCATION MAP.



ViroGroup	AIR • WATER • SOIL TECHNOLOGY	MISSIMER DIVISION
	DRN. BY: CAM DWG NO. A-9342BASE-1 DATE: 3/15/93	
	PROJECT NAME: COLLIER COUNTY - IW-1 NUMBER: 01-09342.00	

FIGURE 2. MAP SHOWING SITE LOCATION AND AREA OF REVIEW.

Injection Well, and one dual zone monitor well. The injection well system was completed in March, 1993.

The entire drilling and construction program was overseen by the FDEP Technical Advisory Committee (TAC), comprised of representatives from the FDEP, the South Florida Water Management District (SFWMD), the U.S. Environmental Protection Agency (USEPA), and the United States Geological Survey (USGS). The TAC met periodically to review construction progress and to approve specific casing seat depths and testing programs. Daily construction logs, weekly construction summaries and other pertinent information were submitted to the TAC weekly.

Construction and testing of the injection well and its associated monitor well were performed in accordance with Florida Administrative Code (FAC) Chapter 17-28 Underground Injection Control (UIC), the conditions of the FDEP construction permit, and the technical specifications prepared by Missimer Division and approved by the TAC.

The construction schedule, outlined in Section 01020 of the Technical Specifications, mandated that the dual zone monitor well construction process identify the base of the Underground Sources of Drinking Water (USDW) aquifers prior to the drilling of the injection well. Similar schedules were adhered to during the construction of the two wells in order to optimize the drilling program.

2.0 GEOLOGY AND HYDROGEOLOGY

2.1. Geology

The geology and hydrogeology of Collier County has been revealed through a number of investigations originated by the U.S. Geological Survey, the South Florida Water Management District, academic research, and by various consultants including Missimer Division. A partial bibliography is given at the end of this report. The terminology used herein conforms to that given in Missimer & Associates, Inc., 1981 and Florida Geological Survey Special Publication 28 and Bulletin Number 59. The geologic column and construction data for both the monitor and the injection wells at the NCRWTP are given in Plate 1 (in envelope, back cover).

The following is a brief description of the geologic formations, aquifers and confining beds encountered within the injection and monitor wells. They are described from youngest to oldest. Geologist's logs of the injection well and monitor wells are given in Appendix C.

Pamlico Sand

The uppermost formation encountered in the wells during drilling is the Pamlico Sand. The unit is only a foot or two thick at the water treatment plant. This surficial, Pleistocene-age deposit occurs throughout most of South Florida. It is predominantly medium to fine grain quartz sand with varying amounts of shell, detrital clays and organic constituents. These sediments are commonly clayey and the development of soil horizons within the unit is common. Local thickness of the unit ranges from 0 to 15 feet. Permeability is generally medium to low depending on the quantity of secondary constituents.

Ft. Thompson/Tamiami Formation (Undifferentiated)

The Fort Thompson Formation consists of 6 feet of alternating fresh-water, marine, and brackish-water marls, limestones, shell beds and sand at the type locality on the Caloosahatchee River, near LaBelle (Parker and others, 1955). In northwestern Collier County, the Fort Thompson consists chiefly of hard sandy limestone and calcareous sandstone containing pockets of quartz sand and thin beds of dense, hard fresh-water limestone.

The Tamiami Formation lies below the Fort Thompson Formation and often includes three distinct member units. These member units in order of increasing depth are the Pinecrest Limestone, the Bonita Springs Marl, and the Ochopee Limestone.

The formal name, Pinecrest Sand Member of the Tamiami Formation, was introduced by Hunter (1968) to name late-to-middle Pliocene shelly sands in Monroe, eastern Collier, Glades, and southern Highlands counties. According to Meeder (1979), Pliocene reefal limestones of Collier and southern Lee County are facies equivalent with the Pinecrest Sand Member and in this report are referred to as the Pinecrest Limestone Member of the Tamiami Formation.

The undifferentiated Fort Thompson Formation and Pinecrest Limestone lie unconformably beneath the Pamlico Sand when it is present. The unit consists of sandy, highly fossiliferous limestones containing varying quantities of mollusk shells, corals, bryozoans, and barnacles. It is characterized by abrupt changes in thickness and lithology and often has a high permeability caused by the secondary dissolution of aragonitic shell. This secondary dissolution of shell creates an abundance of mold and cast type porosity which greatly enhances the storage and flow of water through the formation. Trenching and dewatering at the plant site simultaneous to well construction exposed some very good subcrops of the undifferentiated Fort Thompson/Pinecrest unit. Several small karstic features were observed just below the sand/soil horizon. These features also contribute greatly to the flow of water through this unit. The total thickness of the undifferentiated Fort Thompson/Pinecrest at the site is approximately 25 feet.

A thin sequence of gray marls lies between the Pinecrest and Ochopee Limestone Members of the Tamiami Formation. This unit is referred to in this report as the Bonita Springs Marl Member of the Tamiami Formation. The Bonita Springs Marl is actually a sandy, sometimes shelly, carbonate clay. The amount of fine-grained quartz silt and sand varies from 10 to 30 percent. Other impurities include poorly lithified siltstone, phosphate sand and fossil shells. The overall thickness of the deposit is variable. Permeability of this unit varies based on the relative percentages of clay, quartz sand and shell. In general, the permeability of the sediment is low and declines with depth because of a decrease in the percentage of sand and other impurities. The Bonita Springs Marl is only 5 feet thick at the water treatment plant site.

The Ochopee Limestone Member of the Tamiami Formation was named by Mansfield (1939) for the light gray to white sandy fossiliferous limestone which crops out near the town of Ochopee in Collier County (Hunter, 1968). Lithologically, the Ochopee is a sandy biomicrudite with extensive primary and secondary porosity. The dissolution of shell material, creating large interconnected shell molds, accounts for the high permeability of this unit. Thin beds of sandstone and marl occur near this unit's base. The thickness of the Ochopee is approximately 170 feet at this site which is about 100 feet thicker than that found in the test well drilled at the Collier County water treatment plant approximately 5 miles to the south.

Hawthorn Group

The Hawthorn Group lies unconformably beneath the Tamiami Formation. The Hawthorn Group is regionally extensive and underlies most of Florida and parts of

Georgia and South Carolina. This group includes both carbonate and siliciclastic rock and sediment that are Miocene in age. At this injection well site, the top of the Hawthorn Group occurs at a depth of about 200 feet below land surface and extends down to a depth of about 800 feet below land surface. Beneath the NCRWTP site, two formations within the Hawthorn Group were penetrated; the Peace River and Arcadia Formations.

The upper formation of the Hawthorn Group is the Peace River, which is a phosphatic green sandy dolosilt containing a calcareous sandstone unit at the top and a sandy limestone section near the middle of the formation. This unit extends from 200 feet to 410 feet below land surface at this site.

The Arcadia Formation occurs below the Peace River. The mixed carbonate and clastic assemblage is extremely complex, containing several lithologies including limestone, dolomite, lime mud, and clay. Secondary components of this sequence include sandstone, phosphate, and shell. The majority of the limestones are characterized lithologically as friable biomicrite with interbedded fine lime mud. Most of these limestones lack extensive secondary porosity. Some of the limestones are quite clean, very pale orange in color and have moldic and vuggy porosity. Dolomites in the lower section of the Arcadia Formation are over 100 feet thick and are highly fractured and cavernous in the lower part of this lithology. The total thickness of the Arcadia Formation is approximately 415 feet at this site.

Suwannee Limestone

The upper boundary of the Suwanee Limestone is marked by a change from the light olive-gray, phosphatic dolomite and marl of the Hawthorn Group to a tan to gray, phosphate free, calcarenitic limestone of the Suwannee formation. The contact between the two formations is also characterized by an abrupt attenuation of activity on natural gamma ray logs. Although the contact between the Hawthorn

Group and the Suwannee Limestone is unconformable throughout much of South Florida (Scott, 1988), in the NCRWTP area the contact can be somewhat gradational and is not always obvious in the well cuttings. The present study utilized a combined review of geologists logs and geophysical logs to determine the depth of the contact, which is placed at about 825 feet below land surface.

The Suwannee Limestone is composed of Oligocene-age rocks ranging from unlithified lime muds, to well-consolidated limestones. The characteristic lithology of the Upper Suwannee Limestone is a very pale orange or light tan biomicrite to biosparite (packstone to grainstone) having a medium grained calcarenite texture. Typically, they are moderately indurated and are composed of moderately to well sorted foraminifera, pellets, and abraded echinoderm and mollusk fragments. Porosity is mostly intergranular in the calcarenities and is relatively high in the Upper Suwannee. The lower sequence shows elevated activity on gamma ray logs and is somewhat less porous and occasionally contains sands and phosphate. The Suwanee is 450 feet thick at the injection well site.

Ocala Group

The contact between the Ocala Group and the overlying Suwannee Limestone is marked by a change from the tan calcarenite limestones of the Lower Suwannee Limestone, to the white to very pale orange, chalky coquinoid limestone of the Ocala Group, accompanied by a slight reduction of activity on gamma ray logs.

The Ocala Group is an Upper Eocene-age unit composed primarily of light gray to beige micrites and biomicrites (mudstone to packstones). These limestones exhibit a broad range of textural fabrics ranging from very fine grained, chalky muds to coquina-like grainstones. The Ocala Group is characterized by an abundance of larger foraminifera tests such as Operculinoides sp., Nummulites sp. and Lepidocyclina sp., sometimes comprising the entire rock. The Ocala was subdivided into three distinct units by Puri (1957) when it was elevated to Group status. These three formations are not readily apparent in the subsurface of the NCRWTP area. Detailed paleontological work, which was beyond the scope of this study could provide further subdivisions of the Ocala Group in the study area based on faunal differences. There is a 265 feet section of Ocala occurring at a depth of about 1275 feet to 1540 feet below land surface at the site.

Avon Park Limestone

The Middle Eocene age Avon Park Limestone consists of limestones, minor lime muds and dolomites. The lithology at the top of the unit is very similar to the overlying white, chalky limestones of the Ocala Group. The boundary between the two units was placed at 1540 feet below land surface, where there was a marked increase in activity on the gamma-ray geophysical log. This increase in gamma-ray activity seems to be a fairly common feature at the top of the Avon Park in wells drilled in Southwest Florida. Porosity in the Avon Park Limestone is extremely variable because of variations in depositional textures, which range from mudstones to grainstones (Puri and Winston, 1974), degree of recrystallization of the dolomite, and degree of secondary dissolution. Thickness of the Avon Park Limestone ranges from 250 to 500 feet beneath South Florida (Missimer, 1984). At this site, approximately 475 feet of limestones, muds and dolomites of the Avon Park Limestone were penetrated. A twenty feet thick horizon occurring between 1680 and 1700 feet below land surface contains abundant specimens of the echinoid Neolaganum dalli in a lime mud matrix. This species is said to be very abundant in Florida Peninsula wells in beds referred to the upper 50 feet of the Avon Park Limestone (Vernon, 1951). However, at the NCRWTP site these echinoids occur approximately 140 feet below the top of the formation as interpreted herein.

Oldsmar Limestone

The Lower Eocene age Oldsmar Limestone consists of limestones and dolomites in the upper half of the unit and primarily dolomites in the lower section. This formation was originally described by Applin and Applin (1944) as a biostratigraphic unit consisting of nonclastic rocks in penninsular and northern Florida. Chen (1965) believes that the Oldsmar has conformable relationships with the strata lying above and below the unit. He describes the formation as light brown to chalky white, rather pure, porous, and fossiliferous limestone interbedded with dark brown, rather porous, fine to coarse crystalline, often saccharoid textured dolomite beds.

Commonly existing within the Oldsmar Limestone in South Florida is what is referred to as the "Boulder Zone". The Boulder Zone represents intervals of very high transmissivities and porosities that are present within the cavernous and fractured dolomites. The "Boulder Zone" term is misleading because the zone contains no boulders but rather is an intricate network of vugs, fractures, and caverns found in the lower saline part of the Floridan Aquifer (Deuerling, 1983). The name was first used by drillers exploring for oil in South Florida in the early 1940's to describe a zone which reacts similar to drilling through alluvial boulders. Haberfeld (1991) states that the highly permeable Boulder Zone is recognized on geophysical logs by greatly enlarged hole sizes on the caliper log, exceedingly long sonic transit times, very low resistivity and changes on temperature and flowmeter logs. It has been suggested that the Boulder Zone consists of highly fractured dolomites and that cavities only develop after drill bit penetration (Hickey, 1990).

Because of the highly variable and fractured character of the Boulder Zone, it is often extremely difficult to drill. For example, drilling the NCRWTP injection well pilot hole through this zone took over one months time. The reason for this lengthy drilling process is that the borehole continued to collapse and produced enormous amounts of cuttings at the surface. The reaming operation within this zone encountered similar problems in maintaining the hole although not as severe as in drilling the pilot hole.

The top of the Oldsmar Limestone occurs at a depth of 2015 feet below land surface at the NCRWTP site. There is a sharp break between the limestones of the overlying Avon Park Formation and the hard dark brown dolomite at the top of the Oldsmar. This contact is represented by a large increase in resistivity on the dual induction log and a noteworthy change in the variable density log. By fortuity, the first core taken while drilling the pilot hole contained the Oldsmar-Avon Park contact.

The upper 200 feet of the Oldsmar is predominantly a light gray, finely crystalline, soft limestone with minor beds of hard brown dolomite and lime mud. This unit has fairly low transmissivity values. Below this, down to a depth of approximately 2430 feet, the Oldsmar consists of alternating beds of limestone and dolomites. The limestones are hard and the dolomites are hard with vuggy porosity commonly present. A zone between 2295 and 2330 feet contains highly fractured and cavernous dolomite which is very similar in character to deeper rocks of the "Boulder Zone". Below 2430 feet down to a depth of about 3330 feet below land surface the Oldsmar lithology is almost all dolomite. The lowermost 40 feet of this formation consists of dolomitic limestone with pores filled by gypsum.

The highly permeable "Boulder Zone" in the NCRWTP well extends from approximately 2560 to 3330 feet below land surface. The difficulties encountered while drilling this interval, the geophysical logs and the television surveys all indicate that the zone is highly developed at this location. Major fractures and cavities are present at the below noted intervals:

Cavernous Interval	Vertical Extent (feet)		Depth Below Casing
	Unit	Cumulative	
2580-2610 feet below land surface (bls)	30	30	120
2650-2780 feet bls	130	160	290
2810-2830 feet bls	20	180	340
2910-2975 feet bls	65	245	485
3045-3075 feet bls	30	275	585
3180-3235 feet bls	55	330	745

The composite 770 feet thick Boulder Zone is expected to provide an excellent environment for the injection and storage of the liquid concentrate generated at the NCRWTP. The temperature log conducted one day after the 24-hour injection test showed that the freshwater "bubble" occurred just below the injection casing down to about 2660 feet below land surface (170 feet interval). This indicates that only the upper zone was receiving the injectate during this 4300 gallon per minute test.

Cedar Keys Formation

The oldest rocks penetrated in the NCRWTP well belong to the Cedar Keys Formation of Paleocene age. This formation was originally described by Cole (1944) and later characterized by Chen (1965). In South Florida, the upper Cedar Keys is essentially nonfossiliferous and is composed of microcrystalline dolomite, gypsum and anhydrite. The contact between the Cedar Keys Formation and the overlying Oldsmar Limestone is conformable at a depth of 3370 feet below land surface at the project site. Only twenty feet of this formation was penetrated and it consisted of white to brown anhydrite and olive-gray, finely crystalline dolomite.

2.2 Hydrogeology

The hydrogeology underlying the NCRWTP site is characterized by three major aquifer systems: the Surficial Aquifer System, the Intermediate Aquifer System, and the Floridan Aquifer System. These principal aquifer systems, when combined, extend from near land surface down to a depth of approximately 3370 feet below land surface. Numerous individual aquifers separated by lower permeability confining beds can be identified throughout this Quaternary and Tertiary sequence. However, only aquifers and confining units that will potentially affect the ability of the injection well to function properly and safely will be described herein.

The Surficial Aquifer System underlying the NCRWTP site extends down to a depth of approximately 280 feet below land surface. It includes sediments and rocks of the Ft. Thompson/Tamiami Formation and the upper part of the Peace River Formation. Thin marl units form semi-confining beds at several horizons within this system. Many domestic wells tap the upper portion of this aquifer in the vicinity of NCRWTP and generally have sufficient yields and water quality. The lower units within the Surficial Aquifer contain water that is of brackish quality.

Below the Surficial Aquifer System lies the Intermediate Aquifer System (sometimes referred to as the Intermediate Confining Unit) extending from 280 to 710 feet below land surface. The lower 130 feet of the Peace River Formation forms the top of the system and consists primarily of clay and silt. The upper Arcadia Formation, from 410 feet to about 600 feet is composed of limestones with minor lenses of clay, silt and sand. These rocks have from low to high porosity, but when grouped together, they can produce large quantities of brackish water from wells. The middle Arcadia is characterized by low permeably marls, clays, and marly limestones down to a depth of about 710 feet below land surface. These beds mark the lower boundary of the Intermediate Aquifer System.

The top of the Floridan Aquifer System occurs 710 feet below land surface at the NCRWTP site. It is one of the most productive aquifers in the United States and underlies all of Florida and portions of Georgia, and South Carolina for a total area of about 100,000 mi^2. It consists of an extensive sequence of thickly bedded Tertiary Age carbonate rocks that are hydraulically connected in various degrees to form a regional aquifer system. The system includes permeable sediments of the lower part of the Hawthorn Group, the Suwannee Limestone, the Ocala Group, the Avon Park Limestone, and the Oldsmar Limestone. The base of the system is generally placed at the top of the first occurrence of evaporite beds in the Cedar Keys Formation, and the top of the system is placed at the bottom of the Lower Hawthorn confining unit.

Confining horizons within the Floridan Aquifer System in Collier County range greatly in thickness and vertical conductivity. A thin, limey clay may provide a higher degree of confinement than a much thicker bed of marly limestone. Often, a confining sequence consists of competent limestone or dolomite but which has a much lower hydraulic conductivity than adjacent aquifer units. Vertical fractures and solution features may locally be present within the confining beds, resulting in a higher degree of hydraulic connection between the juxtaposed aquifers.

The uppermost unit of this aquifer system is the lower 120 feet of the Arcadia Formation of the Hawthorn Group. This interval consists primarily of hard dolomites, highly fractured in places, with corresponding high transmissivities.

Underlying these highly permeable dolomites lies the calcarinitic limestones of the Suwannee Formation. A packer test near the middle of this unit indicates a transmissivity of approximately 5000 gpd/ft in the 35 feet interval tested. This value is believed to be representative of the rocks down to about 1300 feet below land surface. The upper monitor zone of the dual zone monitor well at the NCRWTP site is located within this interval. Below these rocks lies the Ocala Group which also consists primarily of calcarenitic limestones. However, they have a finer texture and are somewhat softer than the overlying Suwannee. A packer test conducted in a

35 feet interval near the top of the Ocala indicated a transmissivity of about 1000 gpd/ft which is also thought to be representative for this group of rocks. Thin porous zones do exist within the unit. The base of the "Underground Source of Drinking Water (USDW) is near the Suwannee-Ocala contact at approximately 1200 feet below land surface. A USDW is defined as an aquifer containing water with less than 10,000 mg/l total dissolved solids. All water in the Floridan Aquifer is brackish to saline in Southwest Florida.

The middle confining unit of the Floridan Aquifer System consists primarily of the lower Ocala Group, almost the entire Avon Park Limestone and the upper Oldsmar Limestone. The composite thickness is over 1000 feet with the top of this unit being at approximately 1460 feet below land surface. Packer tests and cores taken while drilling the pilot hole, plus a pump test of the lower monitor zone and the geophysical and television surveys all indicate that this middle confining unit will significantly and sufficiently isolate the lower injection "Boulder Zone" from the Upper Floridan Aquifer. Results of these tests and surveys are presented in a subsequent section.

The lower two-thirds of the Oldsmar Limestone, from approximately 2300 to 3350 feet below land surface, can be classified as the Lower Floridan Aquifer. Transmissivities for some of the dolomites of the Boulder Zone have been reported to be as high as 18.4×10^7 gpd/ft (Singh and other, 1983). These very high values are attributed to diagenetic changes soon after deposition. Groundwater within this unit is very chemically similar to that of seawater. Temperature of the water measured at a depth of approximately 2500 feet below land surface was about 94°F. Pressure at this depth was measured at 1123 psi under static conditions.

3.0 WELL DESIGN AND CONSTRUCTION

3.1 Well Design

Preliminary designs for the NCRWTP injection well and the dual zone monitoring well were completed in compliance with Chapter 17-28 of the Florida Administrative Code and were submitted to the TAC and Collier County Utilities Division for approval in April, 1991. Few design modifications were requested by the TAC which were incorporated in the plans and the final technical specifications were submitted to the TAC in November, 1991. FDEP released its "Intent to Issue Permit" in January, 1992. The actual permit was issued in March, 1992.

In brief, the injection well is of tubing and packer design. The injection casing is 20-inch in diameter and extends down to a depth of 2492 feet bls. The injection tubing with attached packer assembly is 16-inch in diameter and extends to 2450 feet bls. The injection zone is of open hole design and extends from the base of the 20-inch diameter casing down to a depth of 3330 feet bls. Maximum permittable capacity of the well is approximately 6.2 MGD of WTP concentrate based on the tubing diameter and the legal code design standard of 8 feet per second flow velocity. A detailed well construction description is presented below.

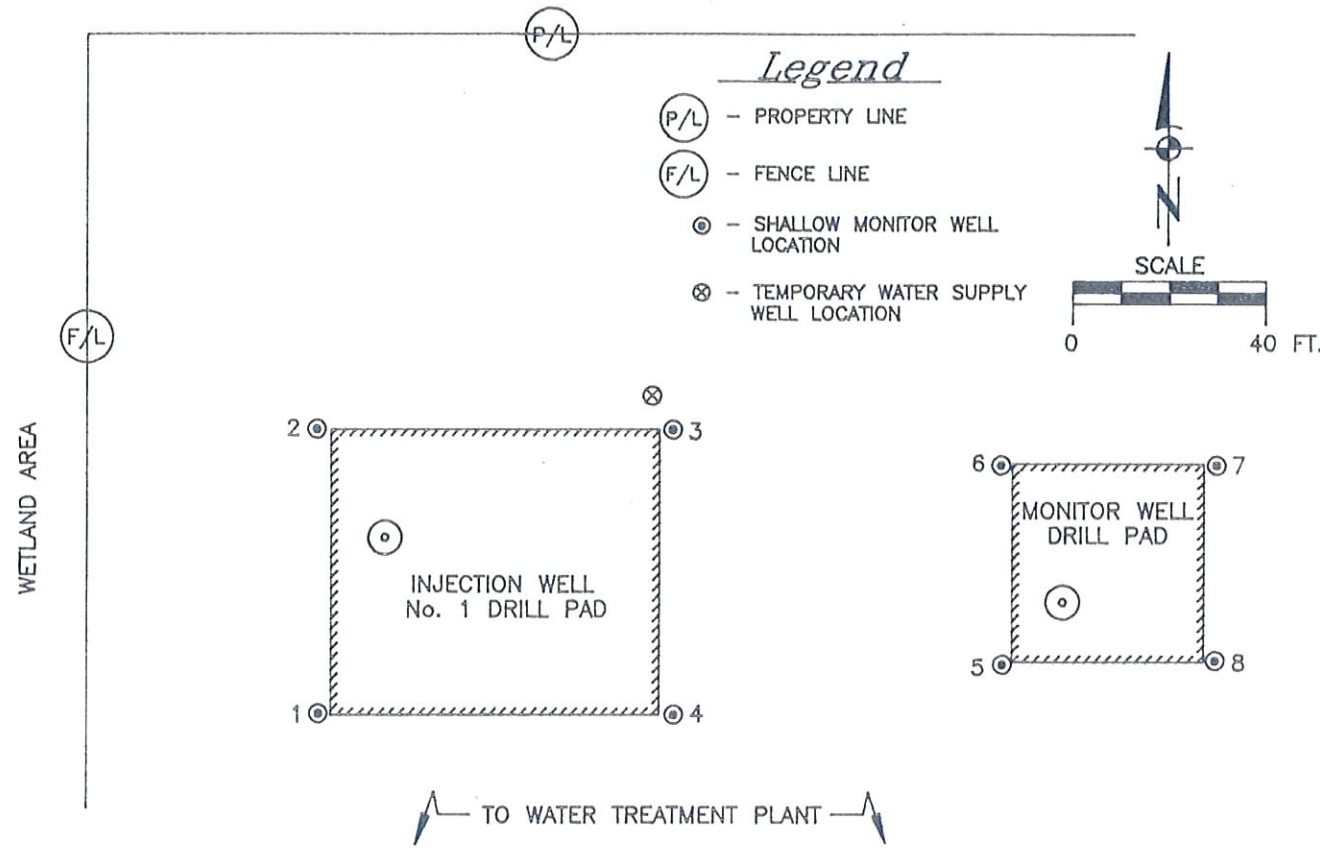
3.2 Site Preparation

The land in the vicinity of the injection and monitor well sites was cleared and rough graded by the water plant contractor prior to mobilizing drilling equipment to the area. The drilling contractor was given the notice to proceed with construction on June 16, 1992 and began site preparation for the two drilling pads on June 18.

The drill sites were prepared by building forms and a framework of steel reinforcing bar and pouring concrete to result in pad thicknesses ranging between 3 and 12 inches depending on how much support was required. Both pads were designed to drain to a shallow sump located at each wellhead. Each pad was finished with a 2 feet high curbing to contain potential spills of water and/or drilling fluids.

Four shallow monitor wells (about 20 feet deep with the lower 10 feet being Schedule 40 PVC slotted pipe, 2-inches in diameter) were constructed at each corner of each pad (8 wells) in order to provide a means of monitoring the surficial aquifer water quality during the construction of the wells. All 8 wells were sampled weekly for chloride concentrations and specific conductance analysis by Missimer Division hydrogeologists on site. The results of these tests are presented in Appendix E.

A 4-inch diameter water supply well was drilled off the northeast corner of the injection well pad for use during drilling operations. This well was drilled to a total depth of about 120 feet and cased to about 50 feet. The Collier County well inspector believed the well penetrated two aquifers and required that the well be back plugged to 80 feet which the contractor reportedly did. A General Water Use Permit, No. 11-1000W, was issued by the South Florida Water Management District (SFWMD) which allowed 2,000 gallons per day on the average or 5,000 gallons per maximum day to be withdrawn from the well. A schematic diagram showing the water supply well, the 8 shallow monitor wells, and a photograph of the injection well drill pad under early construction is presented in Figure 3.



INJECTION WELL DRILL PAD UNDER CONSTRUCTION

ViroGroup	AIR • WATER • SOIL TECHNOLOGY	MISSIMER DIVISION
	DRN. BY: CAM DWG NO. A-0129342AB-1 DATE: 4/13/93	
	PROJECT NAME: COLLIER COUNTY DEEP NUMBER: 01-09342.00	

FIGURE 3. CONFIGURATION OF DRILLING PADS AND SHALLOW MONITOR WELLS.

3.3 Injection Well Construction

Youngquist Brothers, Inc., began construction of the NCRWTP IW-1 on July 10, 1992 following pad construction and drilling set-up. Initially, a 54-inch diameter hole was drilled and then a 48-inch diameter pit casing was installed and cemented in.

Drilling began on July 12, 1992, utilizing the mud-rotary circulation method through the surficial aquifer and the silts and clays of the Peace River Formation down to a depth of 435 feet bpl. A 38-inch diameter conductor casing was set at that depth. Below this depth, the reverse-air circulation method was used to advance the borehole. A complete well construction chronology is presented in Table 1. Construction details of both the monitor well and injection well are presented in Figure 4. The injection wellhead diagram is shown in Figure 5. The wellhead includes a 16-inch diameter gate valve which allows the well to be isolated from the remainder of the system. Construction details of the monitor wellhead are shown in Figure 6.

3.3.1 Casing and Tubing

The conductor and surface casings are black carbon steel conforming to ASTM A-139 Grade B with a wall thickness of 0.375 inches. Final casing and injection tubing conform to ASTMA-53, Grade B, seamless, with a wall thickness of 0.500 inches. Casing ends were mill beveled for butt welding by certified welders using the wire-feed method. All casings of the well were fitted with Halliburton-type centralizers by steel straps at 0, 90, 180 and 270 degrees around the casing at each position and located at specific intervals as stated in Section 04020 of the Technical Specifications.

TABLE 1
WELL CONSTRUCTION CHRONOLOGY:
NCRWTP INJECTION WELL (C0-2317)

DATE[1]	EVENT
June 16, 1992	Collier County issued notice to proceed to Youngquist Brothers, Inc.
June 18-24, 1992	Constructed 8 shallow monitor wells and construction supply well.
June 25, 1992	Both drilling pads complete. Collected first set of weekly water samples from shallow monitor wells to establish baseline water quality prior to drilling deep wells.
July 2, 1992	Missimer Division begins daily construction observation.
July 10-11, 1992	Drilled 54-inch diameter hole from pad level to 16 feet.
July 11, 1992	Installed and cemented 48-inch diameter pit pipe at 16 feet.
July 12-24, 1992	Drilled nominal 48-inch diameter hole from 16 feet to 435 feet.
July 24-25, 1992	Installed 38-inch diameter casing to 425 feet. Cemented annulus with 895 cubic feet 12% gel cement and 712 cubic feet neat cement in one stage.
July 27-30, 1992	Drilled 12 1/4-inch pilot hole from 425 feet to 1325 feet.
July 31, 1992	Ran geophysical logs on 12 1/4-inch hole.
July 31 - Aug. 6, 1992	Reamed nominal 38-inch diameter hole from 417 feet to 1,325 feet.
August 7, 1992	Ran caliper log on nominal 38-inch diameter hole
August 7-8, 1992	Installed 30-inch diameter casing to 1,310 feet.

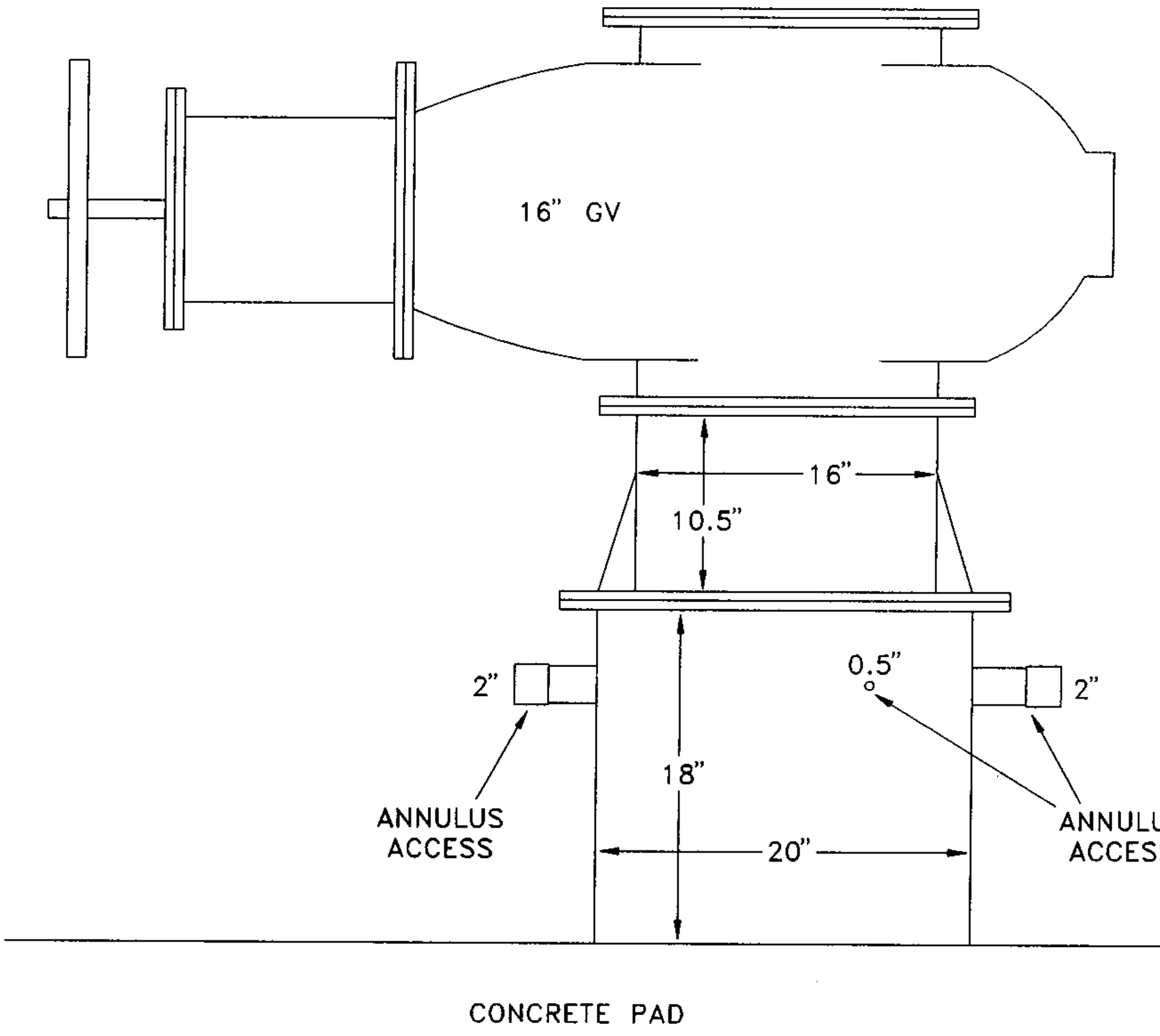
1 For purposes of this study, dates are indicated for the time period from 0800 hours to 0800 hours the following day, based on the shift hours of the well-site geologists.

TABLE 1
WELL CONSTRUCTION CHRONOLOGY:
NCRWTP INJECTION WELL (CO-2317)
- CONTINUED -

DATE	EVENT
August 8-12, 1992	Cemented annulus of 30-inch diameter casing with 674 cubic feet neat cement and 4,796 cubic feet 12% gel cement in seven stages. Conducted temperature log after each stage.
Aug. 13 - Sept. 8, 1992	Drilled 12 1/4-inch pilot hole from 1,320 feet to 3,380 feet.
August 15, 1992	Cored Interval #1 from 2,012 to 2,022 feet (90% recovery).
August 16, 1992	Ran gamma/caliper log and performed single packer test on interval between 1,990 and 2,022 feet.
August 20, 1992	Cored Interval #2 from 2,252 to 2,262 feet (98% recovery).
August 22, 1992	Cored Interval #3 from 2,432 to 2,443 feet (98% recovery).
August 23-24, 1992	No activity due to Hurricane Andrew.
August 25-26, 1992	Ran gamma/caliper log and performed single packer test on interval between 2,470 and 2,512 feet.
August 27, 1992	Cored Interval #4 from 2,582 to 2,588.5 feet (33% recovery).
September 8, 1992	Reached total depth of pilot hole at 3,380 feet.
September 8-14, 1992	Dredged pilot hole between the depths of 2,642 feet and 3,302 feet.
September 14, 1992	Ran geophysical logs on 12 1/4-inch pilot hole.
September 15-17, 1992	Pumped fresh water in hole and ran video survey from 1,310 to 2,668 feet during 3 survey attempts.
September 18-27, 1992	Reamed nominal 30-inch diameter hole from 1,310 feet to 2,500 feet.

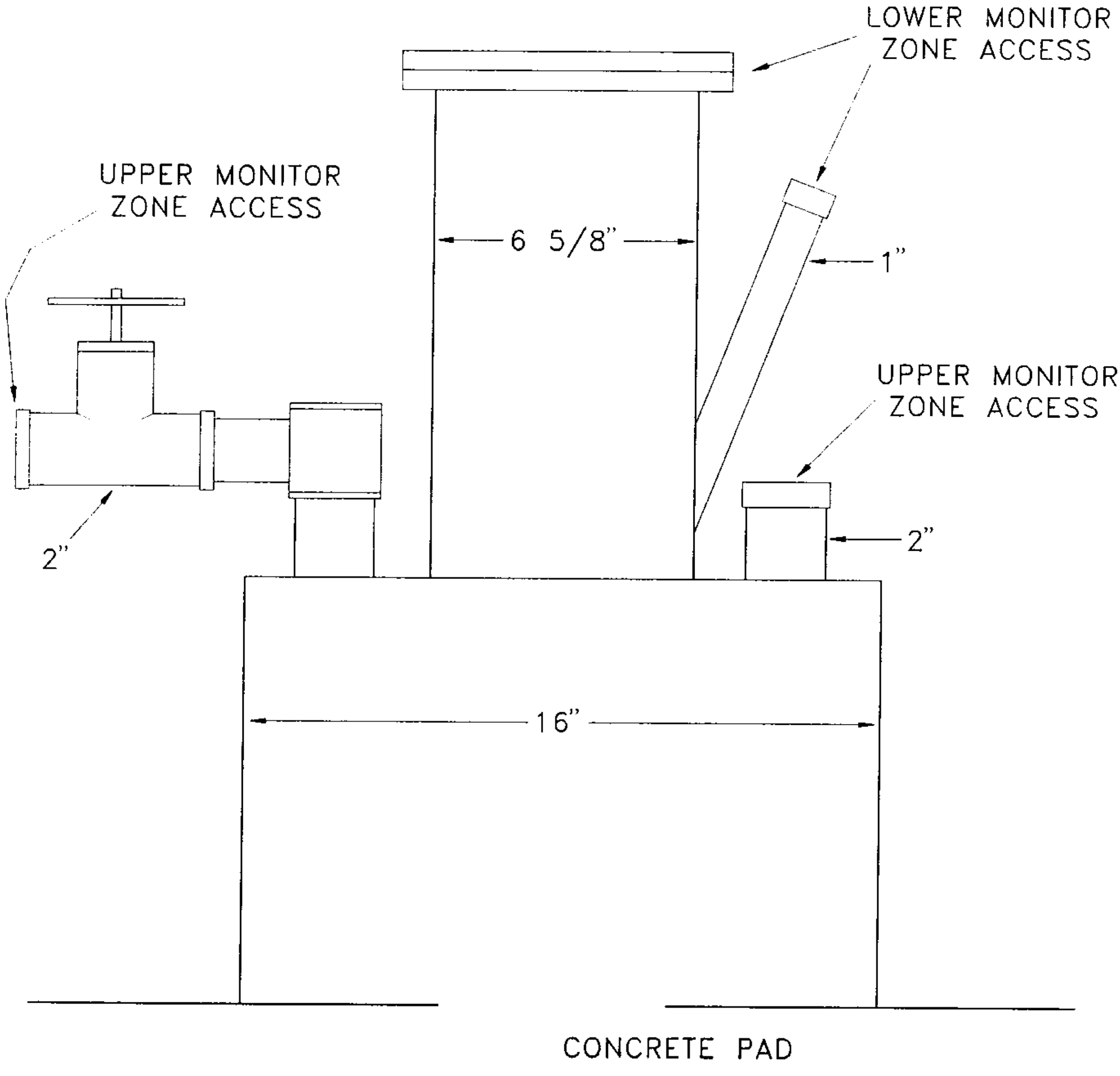
TABLE 1
WELL CONSTRUCTION CHRONOLOGY:
NCRWTP INJECTION WELL (CO-2317)
- CONTINUED -

DATE	EVENT
September 23, 1992	TAC approved depth of 2,492 feet for 20-inch diameter casing.
September 28, 1992	Ran caliper log and began running 20-inch diameter casing.
Sept. 28 - Oct. 1, 1992	Ran 20-inch diameter casing to 2,497 feet.
October 3-6, 1992	Cemented annulus of 20-inch diameter casing with 736 cubic feet of neat cement, 1,067 cubic feet 8% gel cement, and 5,923 cubic feet 12% gel cement in five stages. Conducted temperature log after each stage and ran cement bond log after fourth stage.
October 8-22, 1992	Reamed nominal 20-inch diameter hole from 2,497 feet to 3,330 feet.
October 23, 1992	Ran geophysical logs on 19-inch diameter borehole.
October 24, 1992	Pumped fresh water into well for TV survey.
October 25 1992	Ran TV survey from land surface to 2850 feet.
October 27, 1992	Ran casing scraper.
October 28-30, 1992	Ran 16-inch diameter casing liner and set packer at 2,445 feet.
October 31, 1992	Completed wellhead. Pumped Baricor into annulus and pressurized annulus to 160 psi.
November 2, 1992	Performed pressure test on annulus.
November 4, 1992	Ran TV survey from land surface to 2,580 feet.
February 23, 1993	Began 60 hour injection test program.
February 25, 1993	Conducted Radioactive Tracer Survey.
March 9, 1993	Removed drill rig from site.



ViroGroup	AIR • WATER • SOIL TECHNOLOGY	MISSIMER DIVISION
	DRN. BY: JCS DWG NO. A-019342JD-1 DATE: 8/17/93	
	PROJECT NAME: COLLIER IW-1 NUMBER: 01-09342.00	

FIGURE 5. INJECTION WELL – WELLHEAD CONSTRUCTION DETAILS.



ViroGroup	*AIR • WATER • SOIL TECHNOLOGY*	MISSIMER DIVISION
	DRN. BY: JCS DWG NO. A-019342JC-1 DATE: 8/17/93	
	PROJECT NAME: COLLIER IW-1 NUMBER: 01-09342.00	

FIGURE 6. DUAL ZONE MONITOR WELL – WELLHEAD CONSTRUCTION DETAILS.

The pit casing (48-inch) is set through surficial sand, silt and shell down to a depth of 16 feet. The conductor casing (38-inch) is set through the Peace River Formation sands, clays and marls and just into the top of the Arcadia Formation limestone. The third, or surface casing (30-inch) is set to isolate underground sources of drinking water (USDW) aquifers from the more saline water aquifers below. Based on packer tests conducted in the monitor well pilot hole, the base of the USDW occurs at an approximate depth of 1200 feet bls. Therefore, the surface casing was placed to 1310 feet bls, thereby isolating the USDW aquifers.

Following the setting of 30-inch diameter casing, a 12 1/4-inch diameter pilot hole was drilled to a depth of 3390 feet bpl, penetrating the entire thickness of the Oldsmar Limestone and about 770 feet of highly fractured "Boulder Zone" in the lower part of the Oldsmar. This pilot hole was then reamed to about 2500 feet bpl followed by setting the injection casing string (20-inch) to a depth of 2492 feet bpl. After grouting in the injection casing, the injection zone pilot hole was reamed to a nominal 20-inch diameter down to a depth of 3330 feet bpl.

Prior to running the 16-inch injection tubing, a casing scraper was employed in the 20-inch diameter casing to remove any jagged imperfections which may exist and possibly damage the packer during its installation.

A Texas Iron Works (TIW), type LH packer assembly was welded to the base of the 16-inch diameter tubing. This packer has a polished barrel and a 4 unit O-ring seal group and is said to be fully retrievable by the manufacturer. The packer was lowered to a depth of approximately 2450 feet bpl and was set at this depth, about 42 feet above the base of the 20-inch diameter casing. A sketch and photograph of this TIW packer are presented in Figure 7. A summary of the injection well casing material specifications and dimensions is tabulated in Table 2. Mill certificates for all casing installed in the injection well are provided in Appendix F.

TABLE 2

CASING SUMMARY
INJECTION WELL

OUTSIDE DIAM. (in.)	CONSTRUCTION TYPE	WALL THICKNESS (in.)	WT/FT (lbs.)	TOTAL LENGTH (ft.)	STRING WT (lbs.)
48	ASTM A-53 GR.B SPIRAL WELD	0.375	191.0	16	3,056
38	ASTM A-139 GR.B SPIRAL WELD	0.375	151.5	425	64,388
30	ASTM A-139 GR.B SPIRAL WELD	0.375	119.8	1310	156,938
20	ASTM A-53 GR.B SEAMLESS	0.500	104.1	2497	259,938
16	ASTM A-53 GR.B SEAMLESS	0.500	82.8	2445	202,446

TABL5/01-09342.00/GNG

3.3.2 Cementing Program - Injection Well

Casings were cemented into place with ASTM Type II cement by pressure grouting the first stage and by the tremie method for subsequent stages. The cement was installed by Florida Cement, Inc. of Ft. Myers, Florida. Cement was installed in stages, with a temperature log run between stages to verify the presence of cement throughout the interval and to locate the top of each stage. The bottom 200 feet of the surface and final casings and the bottom 100 feet of the intermediate casings in the injection well were cemented with neat cement; other stages were cemented with a maximum of 12% bentonite gel. Table 3 summarizes the cementing program for the injection well.

3.4 Construction of Dual Zone Monitor Well

The dual-zone monitor well is required to detect potential upward migration of injection fluid above the confining zones into overlying USDW aquifers. Construction of the monitor well began on July 2, 1992. The monitor well was constructed using similar methods as those used on IW-1. The mud-rotary drilling method was employed to a depth of 425 feet bpl, after which reverse air was used for the remainder of the well. A complete well construction chronology is listed in Table 4.

3.4.1 Casing

Three strings of casing were used to construct DMW-1. The casing depths were selected based on lithologic, geophysical, hydrogeologic, and water quality data obtained during construction and testing of IW-1 and DMW-1. Setting of the final two casing strings was not permitted until testing was complete in both the injection well and DMW-1. After completing the packer tests in the DMW-1 and the base of the USDW determined, the TAC was consulted and the 16-inch diameter seat (top

TABLE 3. INJECTION WELL CEMENT SUMMARY

CASING DIAMETER: 38 INCH CASING DEPTH: 425 FEET BPL

CEMENT STAGE NO.	DATE	CEMENT MIXTURE	BBLS PUMPED	CUBIC FEET PUMPED	SACKS PUMPED	TAG DEPTH (FEET)
1	7-25-92	12% GEL NEAT	160 127	895 712	407 603	12

CASING DIAMETER: 30 INCH CASING DEPTH: 1310 FEET BPL

CEMENT STAGE NO.	DATE	CEMENT MIXTURE	BBLS PUMPED	CUBIC FEET PUMPED	SACKS PUMPED	TAG DEPTH (FEET)
1	8-08-92	12% GEL NEAT	140 120	786 674	357 571	895
2	8-10-92	12% GEL	115	646	293	792
3	8-10-92	12% GEL	90	505	230	700
4	8-11-92	12% GEL	112	629	286	660
5	8-11-92	12% GEL	120	674	306	475
6	8-12-92	12% GEL	110	618	281	355
7	8-12-92	12% GEL	167	938	426	2

TABLE 3. INJECTION WELL CEMENT SUMMARY
- CONTINUED -

CASING DIAMETER: 20 INCH CASING DEPTH: 2492 FEET BPL						
CEMENT STAGE NO.	DATE PUMPED	CEMENT MIXTURE	BBLS PUMPED	CUBIC FT. PUMPED	SACKS PUMPED	TAG DEPTH (FEET)
1	10-3-92	NEAT	131	736	624	2308
2	10-4-92	8% GEL	190	1067	556	2005
3	10-4-92	12% GEL	373	2094	952	1420
4	10-5-92	12% GEL	600	3369	1531	210
5	10-6-92	12% GEL	82	460	209	3

TABLE 4
WELL CONSTRUCTION CHRONOLOGY:
NCRWTP DUAL-ZONE MONITOR WELL (CO-2318)

DATE[1]	EVENT
June 18-24, 1992	Constructed 4 shallow monitor wells around perimeter of Dual-Zone Monitor Well (DZM well) pad.
June 25, 1992	Collected first set of weekly water samples from shallow monitor wells to establish baseline water quality prior to drilling well.
July 2, 1992	Missimer Division begins daily construction observation.
July 2-9, 1992	Drilled 30-inch diameter hole from 22 feet to 430 feet.
July 10, 1992	Installed 24-inch diameter steel casing to 420 feet and cemented annulus with 298 cubic feet neat cement and 382 cubic feet of 12% gel cement.
July 11, 1992	Ran temperature log on 24-inch diameter casing.
July 13-20, 1992	Drilled 9-inch diameter pilot hole from 420 feet to 1331 feet.
July 17-18, 1992	Ran caliper log on pilot hole and ran single packer test on interval from 1012 feet to 1052 feet.
July 21, 1992	Ran caliper log on pilot hole and ran single packer test on interval from 1306 feet to 1331 feet.
July 22-30, 1992	Reamed nominal 24-inch diameter hole from 425 feet to 910 feet.
August 2, 1992	Ran caliper log on nominal 24-inch diameter hole and installed 16-inch diameter casing to 900 feet.
August 6, 1992	Created bridge plug from 910 feet to 1,146 feet with #86 coarse aggregate.

1 For purposes of this study, dates are indicated for the time period from 0800 hours to 0800 hours the following day, based on the shift hours of the well-site geologists.

TABLE 4
WELL CONSTRUCTION CHRONOLOGY:
NCRWTP DUAL-ZONE MONITOR WELL (CO-2318)
- CONTINUED -

DATE	EVENT
August 7-12, 1992	Cemented annulus of 16-inch diameter casing with 780 cubic feet neat cement and 1656 cubic feet 12% gel cement in six stages. Conducted temperature log after each stage.
August 13, 1992	Ran cement bond log on 16-inch diameter casing.
August 23-24, 1992	Secured rig and suspended operations for Hurricane Andrew.
September 4, 1992	Conducted pressure test on 16-inch diameter casing.
September 8, 1992	DER tentatively approved drilling to a depth 1600 feet pending the next TAC meeting.
September 9-14,1992	Drilled nominal 16-inch diameter hole from 900 feet to 1584 feet.
September 23, 1992	TAC approved the interval from 1820 feet to 1930 feet for the lower monitor zone.
September 24-28, 1992	Resumed drilling nominal 16-inch diameter hole from 1584 feet to 1825 feet.
October 4, 1992	Ran geophysical logs (gamma ray, caliper, flowmeter, and temperature) on nominal 16-inch diameter hole.
October 5-6, 1992	Ran 6 5/8-inch diameter casing to 1,815 feet.
October 6-8, 1992	Cemented annulus of 6 5/8-inch diameter casing with 971 cubic feet of neat cement in five stages. Conducted temperature log after each stage.
October 9, 1992	Ran cement bond log on 6 5/8-inch diameter casing.
October 12, 1992	Conducted pressure test on 6 5/8-inch diameter casing.

TABLE 4
WELL CONSTRUCTION CHRONOLOGY:
NCRWTP DUAL-ZONE MONITOR WELL (CO-2318)
- CONTINUED -

DATES	EVENT
October 12-13, 1992	Drilled nominal 6-inch diameter hole from 1,815 feet to 1,930 feet.
October 15, 1992	Ran geophysical logs (gamma ray, caliper, flowmeter, and temperature) on nominal 6-inch diameter lower monitor zone.
October 14-15, 1992	Mobilized drill rig off-site.
October 15-22, 1992	Developed both monitor zones.
October 16-17, 1992	Chlorinated both monitor zones. Suspended development to allow for 24-hour disinfection period.
October 20, 1992	Collected water samples from both monitor zones for primary and secondary analyses.
October 22, 1992	Collected water samples from both monitor zones for USGS and FDEP.

of the upper monitor zone) was determined. A TAC meeting was held on September 23, 1992 to review the data collected from drilling IW-1 pilot hole and evaluate Missimer Division's proposed lower casing seat point and top of the lower monitor zone. Table 5 summarizes the casings used in the construction of DMW-1.

3.4.2 Cementing Program - Dual Zone Monitor Well

Casings in the monitor well were cemented into place in a similar method as that employed in the injection well. Cement was installed in stages, with a temperature log run between stages to verify the presence of cement throughout the interval and to locate the top of each stage. Table 6 summarizes the cementing program for the monitor well.

38

TABLE 5

CASING SUMMARY
DUAL ZONE MONITOR WELL

OUTSIDE DIAM. (in.)	CONSTRUCTION TYPE	WALL THICKNESS (in.)	WT/FT (lbs.)	TOTAL LENGTH (ft.)	STRING WT (lbs.)
30	ASTM A-139 GR.B SPIRAL WELD	0.375	118.7	20	2,374
24	ASTM A-139 GR.B SPIRAL WELD (JOINTS 1-8 AND 11)	0.375	94.62	345	32,644
24	ASTM A-53 GR.B SPIRAL WELD (JOINTS 9 AND 10)	0.375	94.62	80	7,570
16	ASTM A-53 GR.B SEAMLESS	0.656	96.34	900	86,704
6.625	ASTM A-53 GR.B SEAMLESS	0.562	36.39	1815	66,048

TABL5/01-09342.00/GNG

TABLE 6. DUAL ZONE MONITOR WELL CEMENT SUMMARY

CASING DIAMETER: 24 INCH CASING DEPTH: 425 FEET BPL

CEMENT STAGE NO.	DATE	CEMENT MIXTURE	BBLS PUMPED	CUBIC FEET PUMPED	SACKS PUMPED	TAG DEPTH (FEET)
1	7-10-92	12% GEL NEAT	68 53	382 298	174 253	1

CASING DIAMETER: 16 INCH CASING DEPTH: 900 FEET BPL

CEMENT STAGE NO.	DATE	CEMENT MIXTURE	BBLS PUMPED	CUBIC FEET PUMPED	SACKS PUMPED	TAG DEPTH (FEET)
1	8-07-92	NEAT	25	140	119	829
2	8-10-92	NEAT	39	219	186	805
3	8-11-92	NEAT	75	421	357	702
4	8-11-92	12% GEL	94	528	240	670
5	8-12-92	12% GEL	93	522	237	442
6	8-12-92	12% GEL	108	606	276	245
7	10-5-92	12% GEL	67	376	171	2

TABLE 6. DUAL ZONE MONITOR WELL CEMENT SUMMARY
- CONTINUED -

CASING DIAMETER: 6 5/8 INCH CASING DEPTH: 1815 FEET BPL

CEMENT STAGE NO.	DATE PUMPED	CEMENT MIXTURE	BBLS PUMPED	CUBIC FT. PUMPED	SACKS PUMPED	TAG DEPTH (FEET)
1	10-6-92	NEAT	62	348	295	1540
2	10-7-92	NEAT	10	56	48	1478
3	10-7-92	NEAT	41	230	195	1300
4	10-8-92	NEAT	40	225	190	1098
5	10-8-92	NEAT	20	112	95	995

4.0 HYDROGEOLOGICAL TESTING/DATA COLLECTION

During the construction of both the injection well and the dual-zone monitor well, specific information was collected to determine the hydraulic characteristics and geologic nature of the underlying formations. The data were utilized to verify the alignment of the boreholes and in the determination of confining intervals, monitoring zones, and casing seating depths.

4.1 Inclination Surveys

Inclination refers to the degree of deviation of the borehole from a true vertical alignment. Inclination surveys as required in FAC 17-28 220 (3)(a), and as specified in the FDEP construction permit, were conducted at 60 foot intervals throughout the construction process of each well in order to monitor the amount of deviation of the hole while drilling. The maximum allowable inclination is one degree (60 minutes), and the maximum allowable difference between any two successive surveys is one-half of a degree (30 minutes). If a survey indicated that the deviation was approaching the allowable limits, measures were to be taken to remediate the condition. This situation occurred only once during the drilling of the two wells, in the dual-zone monitor well at 486 feet below the drilling pad, at the beginning of the 9-inch pilot hole. The situation was immediately rectified.

Each survey was conducted by sending a TOTCO "sure-shot" deviation survey tool on a wire line inside the drill pipe to a specified depth above the drill bit. The surveys were recorded on a paper disk which indicates the degree of deviation from the vertical. A record of each inclination survey is presented in Appendix G.

4.2 Formation Sampling

Samples were retrieved from the drill cuttings at a minimum of 10-foot intervals, at drill rod connections, and at formation changes. Two sets of samples were collected and distributed to the Florida Geological Survey and to Missimer Division. Splits from the samples were washed and described on site as they were collected. These lithologic descriptions are included as Appendix C.

4.3 Formation Fluid Sampling

Water samples were collected from the discharge line every 30 feet during reverse-air drilling of the pilot hole in both the injection and monitor wells. These samples of the air-lifted water from the bit depth at each drilling rod change were analyzed in the field for chloride concentration and specific conductivity as required by the FDEP.

Formation fluid samples were collected from the monitor well pilot hole between the depths of 457 and 1331, and from the injection well pilot hole between the depths of 454 and 3362 feet below pad level. The results of the field analyses are presented in Appendix E.

4.4 Coring Program

During the drilling of the 12 1/4-inch diameter pilot hole in the injection well, four 4-inch diameter cores were recovered from the confining units overlying the injection zone. Data retrieved from laboratory analyses of the physical and mechanical properties of these cores were used to characterize the confinement.

Cores were taken with a 4-inch diameter, 10-foot long, carbide-tipped core barrel. Coring depths were selected between 2012 to 2582 feet below pad level, with three of the four cores resulting in more than 90 percent recovery. A summary of the coring program is presented in Table 7.

A total of 12 oriented core samples were sent to Core Laboratories of Carollton, Texas, for analysis. The samples were analyzed for horizontal and vertical permeability, porosity, grain density, elastic moduli, and compressive strength. Vertical permeabilities ranged from less than 0.01 meter/day to 5.51 meters/day in all core samples taken below 2016 feet below pad level, and were consistently less than 0.01 meter/day below 2433 feet bpl. The physical data are summarized in Table 8, while detailed lithologic, physical, and mechanical data are presented in Appendix C.

4.5 Geophysical Logs

Geophysical logs were run in the injection well after each stage of the pilot hole was completed, prior to the reaming of the borehole. These logs, plus the logs run on the reamed boreholes prior to and after the setting and cementing of casing strings were used to help determine pertinent hydrogeologic characteristics of the penetrated strata and base further well construction decisions. Geophysical logs were also utilized to evaluate the integrity of the cementing of the casing.

The borehole geophysical surveys involved the lowering of sensing devices into the borehole to measure and record various physical properties of the penetrated strata. The rocks, the formation fluids, and the quality of the well construction were all evaluated in this way. Casing setting depths, cement volume calculations, formational characteristics and changes, monitor zones, packer test intervals, and mechanical integrity of the cementing procedures were among the properties

TABLE 7
CORING PROGRAM SUMMARY
NCRWTP INJECTION WELL #1

Core Number	Date Cored	Interval Cored (feet bpl)	Percent Recovered
1	8-15-92	2,012-2,022	90%
2	8-20-92	2,252-2,262	98%
3	8-22-92	2,432-2,443	98%
4	8-27-92	2,582-2,588.5	33%

TABLE 8
CORE ANALYSIS RESULTS
NCRWTP INJECTION WELL #1

Core No.	Sample No.	Depth (ft)	Permeability Horizontal Kair[1] md[2]	Vertical Kair[1] md[2]	Porosity (Helium) %	Grain Density g/cm3	Description
1	1H	2013.6	55.0		23.9	2.70	
	1V	2013.7		82.7	24.8	2.70	Ls lt gry chlky
	2H	2016.1	8.39		27.0	2.70	
	2V	2016.3		5.51	26.7	2.69	Ls lt gry chlky
	3H	2021.4	0.01		5.7	2.82	
	3V	2021.4		<.01	5.4	2.81	Dol lt brn xln
2	4H	2253.3	1.55		20.2	2.69	
	4V	2253.3		1.60	20.1	2.69	Ls lt gry chlky
	5H	2255.7	4.25		21.0	2.69	
	5V	2255.8		4.49	20.9	2.69	Ls lt gry chlky
	6H	2259.7	0.49		19.1	2.68	
	6V	2259.5		0.45	19.5	2.68	Ls lt gry chlky
3	7H	2432.8	1.15		16.4	2.72	
	7V	2432.8		0.64	16.0	2.72	Ls lt gry chlky
	8H	2433.1	<.01		6.5	2.83	
	8V	2433.1		<.01	4.5	2.79	Dol gry xln calc
	9H	2440.2	0.03		6.2	2.72	
	9V	2440.2		<.01	1.9	2.73	Dol brn xln lam
	10H	2442.0	<.01		7.9	2.84	
	10V	2442.1		<.01	2.4	2.80	Dol lt gry xln
4	11H	2583.8	<.01		5.4	2.83	
	11V	2583.8		<.01	4.0	2.79	Dol brn xln dns
	12H	2584.2	<.01		5.8	2.82	
	12V	2584.1		<.01	6.7	2.83	Dol brn xln dns

[1] Permeability to air at 800 psig net confining stress.

[2] Millidarcy

investigated. A summary of all borehole geophysical logs run on each of the two wells is listed in Tables 9 and 10.

4.6 Television Surveys

The pilot hole and various sections of the cased injection well were surveyed with a black and white TV camera on four different occasions. These surveys provided the data necessary for general qualitative observations to be made with regard to the nature of the rocks penetrated and of the integrity of the completed sections of casing and the final injection tubing/packer assembly. A summary of the TV surveys run can be seen in Table 11. A general description of observations of the TV scans of the pilot hole from 1310 to 2668 feet bpl and the reamed hole from 2495 to 2850 feet bpl may be found in Appendix H.

4.7 Single Packer Tests

Three single packer tests were performed on the pilot hole in the injection well between the depths of 1990 and 2470 feet below pad level; two tests were performed in the dual zone monitor well between the depths of 1010 and 1300 feet below pad level. The tests were conducted in order to characterize the hydrogeology and the water quality of the formations. This information was used to evaluate the location and degree of confinement available in the Middle Confining Unit between the Upper Floridan Aquifer and the Boulder Zone and to determine the location and productivity of the upper and lower monitor zones. Water samples collected during the tests were used to locate the base of the Underground Source of Drinking Water (USDW), defined as the depth at which total dissolved solids (TDS) exceed 10,000 mg/l. This depth was determined to be at approximately 1200 feet below pad level. A summary of the packer test program, including calculated

TABLE 9
COLLIER COUNTY
NCRWTP GEOPHYSICAL LOGS THRU 10/24/92

Injection Well CO-2317

Log Date	Log Type	Logged Interval	Comments
07/25/92	Caliper & Gamma Ray	0 to 444'	Prior to 38" casing install.
07/26/92	Temperature	0 to 420'	Grouting 38" casing.
07/31/92	Temperature	25 to 1320'	Pilot hole.
07/31/92	Caliper & Gamma Ray	416 to 1320'	Pilot hole.
07/31/92	Dual Induction & Gamma Ray	416 to 1320'	Pilot hole.
07/31/92	Flowmeter	350 to 1320'	Pilot hole (pumping).
07/31/92	BHC Sonic	420 to 1320'	Pilot hole.
08/07/92	Caliper & Gamma Ray	400 to 1250'	Prior to 30" casing install.
08/09/92 to 08/13/92	Temperature	0 to 1266'	Grouting 30" casing.
08/16/92	Caliper & Gamma Ray	1300 to 2000'	Pilot hole, prior to packer test #1.
08/18/92	Caliper, Gamma Ray	1300 to 2132'	Pilot hole, prior to packer test #2.
08/26/92	Caliper, Gamma Ray	1300 to 2512'	Pilot hole prior to setting packer #3.
09/14/92	Caliper, Gamma Ray	1250 to 2846'	Pilot hole.
09/14/92	Flowmeter	1300 to 2670'	Pilot hole.
09/14/92	DIL, SP, Gamma Ray	1300 to 2846'	Pilot hole.

TABLE 9
COLLIER COUNTY
NCRWTP GEOPHYSICAL LOGS THRU 10/24/92
Continued:

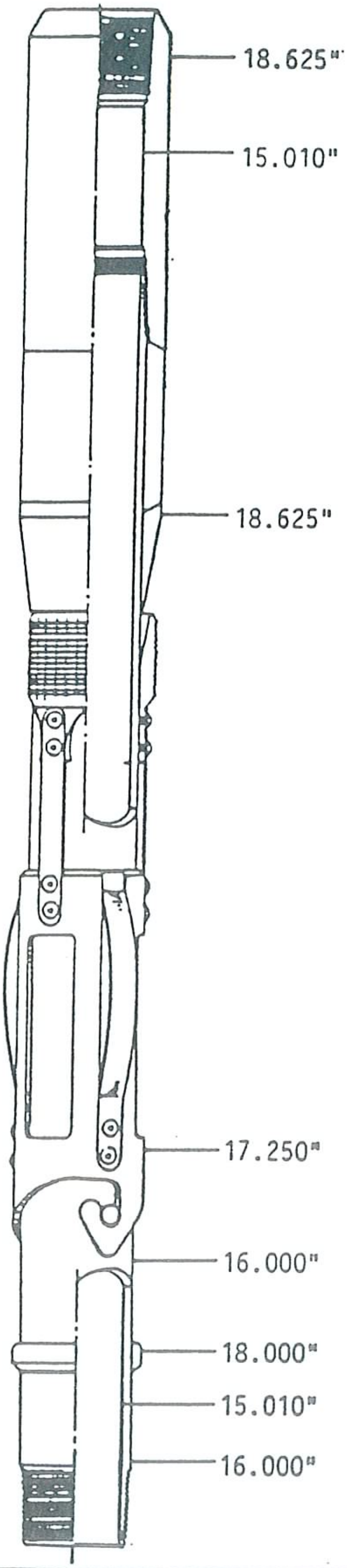
Injection Well CO-2317

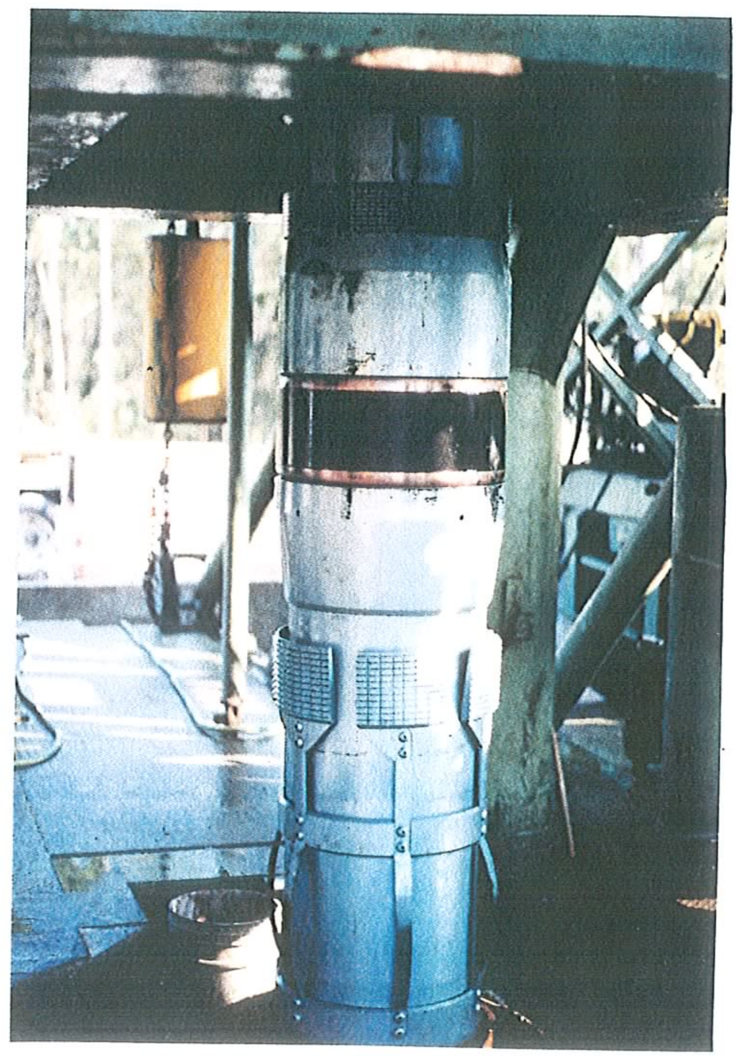
Log Date	Log Type	Logged Interval	Comments
09/14/92	Temperature	1300 to 2840'	Pilot hole.
09/14/92	BHC, Sonic, VDL	1300 to 2840'	Pilot hole.
09/28/92	Caliper & Gamma Ray	1300 to 2502'	Prior to setting 20" casing.
10/03/92 to 10/06/92	Temperature	0 to 2485'	Grouting 20" casing.
10/06/92	Sonic Bond	50 to 2475'	20" casing.
10/24/92	DIL, Sp, Gamma Ray	2490 to 3342'	Open hole.
10/24/92	BHC, Sonic, VDL, Gamma Ray	2480 to 3342'	Open hole.
10/24/92	Flowmeter	2450 to 3340'	Open hole.
10/24/92	Caliper, Gamma Ray	2450 to 3342'	Open hole.
10/24/92	Temperature	2450 to 3342'	Open hole.

TABLE 10
COLLIER COUNTY
NCRWTP GEOPHYSICAL LOGS THRU 10/24/92

Monitor Well CO-2318

Log Date	Log Type	Logged Interval (ft)	Comments
07/11/92	Temperature	0 to 405	Grouting 24" casing.
08/02/92	Caliper & Gamma	425 to 910	Prior to 16" casing install.
08/08/92 to 08/13/92	Temperature	0 to 888	Grouting 16" casing.
08/13/92	Sonic Bond	25 to 822	16" casing.
10/04/92	Flowmeter	890 to 1820	16" borehole prior to setting 6 3/8 casing.
10/04/92	Temperature	850 to 1827	16" borehole prior to setting 6 3/8 casing.
10/04/92	Caliper, Gamma Ray	880 to 1827	16' borehole prior to setting 6 3/8 casing.
10/06/92	Sonic Bond, VDL	50 to 2475	6 5/8" casing.
10/07/92 to 10/09/92	Temperature	800 to 1760	Grouting 6 5/8" casing.
10/09/92	Sonic Bond	850 to 1755	6 5/8" casing.
10/15/92	Flowmeter	1750 to 1926	Open hole.
10/15/92	Temperature	1700 to 1926	Open hole.
10/15/92	Caliper, Gamma Ray	1800 to 1926	Open hole.





ViroGroup	AIR • WATER • SOIL TECHNOLOGY	MISSIMER DIVISION
	DRN. BY: CAM DWG NO. A-019342AA-1 DATE: 4/13/93	
	PROJECT NAME: COLLIER COUNTY DEEP NUMBER: 01-09342.00	

FIGURE 7. T.I.W. TYPE LH PACKER WITH POLISHED BORE AND 0-RING SEAL ASSEMBLY

TABLE 11
SUMMARY OF TELEVISION SURVEYS
INJECTION WELL

Video No.	Video Date (Depths - ft bpl)	Completion Status and Comments
1	9/15/92 (2450-2668) (2668-2500)	30" casing set 12 1/4" pilot hole complete (3380') Pilot hole bridged @ 2668' (not clear)
2	9/17/92 (1380-2669)	30" casing set to 1310' 12 1/4" pilot hole complete Pilot hole bridged @ 2669'
3	10/25/92 (100-2850)	20" casing set to 2497' Pilot hole reamed to 3330' Reamed hole murky below 2830'
4	11/4/92 (10-2580)	16" injection liner set to 2450' with attached TIW packer Last TV scan of well

c:\wp-tabl5\09342TBW.E15

hydraulic coefficients, is provided in Table 12 for the monitor well and Table 13 for the injection well.

The procedures used for conducting the straddle packer tests were as follows:

1. Intervals to be tested were selected based upon geologic logs, geophysical logs, and caliper logs.
2. A single inflatable packer was connected to the drill pipe.
3. The tool was lowered to the selected depth (typically 30 to 40 feet above bottom of pilot hole at time of testing).
4. A five horsepower submersible pump was set inside the drill pipe at approximately 150 feet below pad level.
5. The pump was run to clear drilling fluid from the formation, then shut off.
6. The packer was inflated, isolating the portion of the formation below the packer from the overlying strata. The seal of the inflatable packer against the pilot hole wall was checked, and the water level within the drill pipe was allowed to come to a static condition.
7. The open zone was pumped at each of three rates while recording water levels, water temperature and conductivity. Pumping was continued at a constant rate until the water level stabilized, then the rate was stepped up.
8. Water samples were taken for laboratory analysis at the end of each test (monitor well only).
9. The submersible pump was shut off and recovery data was gathered.

4.8 Evaluation of Confining Units

The location and degree of confinement provided by the low-transmissivity rocks overlying the injection zone were evaluated by the examination of the cores

TABLE 12

PACKER TEST SUMMARY
COLLIER COUNTY NCRWTP
DUAL ZONE MONITOR WELL (CO-2318)

DEPTH (ft. bpl)	PUMPING RATE (gpm)	SPECIFIC CAPACITY (gpm/ft)	ESTIMATED HYDRAULIC CONDUCTIVITY (ft/day)	TDS (mg/l)	Cl^- (mg/l)
1010 - 1050	16.0	2.52	16		2120
	56.0	1.76	11		2120
	86.0	1.53	10	4500	2140
1300 - 1331	15.0	0.39	3		8900
	25.0	0.35	3		8900
	44.0	0.62	5	16600	8900

09342TCH.H11

TABLE 13

PACKER TEST SUMMARY
COLLIER COUNTY NCRWTP
INJECTION WELL (CO-2317)

DEPTH (ft. bpl)	PUMPING RATE (gpm)	SPECIFIC CAPACITY (gpm/ft)	ESTIMATED HYDRAULIC CONDUCTIVITY (ft/day)
1990 - 2022	4.0	0.032	0.25
	5.0	0.037	0.29
	6.0	0.043	0.33
2050 - 2090	5.0	0.056	0.33
	7.5	0.062	0.40
	9.0	0.061	0.40
2470 - 2512	5.2	6.50	38
	7.0	5.30	32
	40	3.96	22

09342TCH.H11

retrieved, by the single packer tests, and by the examination of certain geophysical logs and TV surveys which were run during the drilling of the wells. Useful logs included the BHC sonic, VDL, flowmeter, caliper, and gamma ray logs of the pilot holes.

Laboratory tests on the cored intervals indicated that vertical confinement was achieved between 2010 and 2540 feet below pad level. Other evidence supporting the confining nature of this interval is found by comparing the calibrated flowmeter, caliper, BHC sonic, VDL, and gamma ray logs of the pilot hole. Within the confining interval a marked reduction in calibrated flow velocity, sonic log records short travel times, the VDL qualitatively corresponds to lithology and sometimes a low intensity natural gamma ray count (indicating a clean limestone or dolomite) can indicate satisfactory confinement.

A semi-quantitative analysis of the degree on confinement between the lower monitor zone and the injection zone, based on the TV scan of the pilot hole as well as core data and other logs and tests, is presented in Table 14.

TABLE 14
SEMI-QUANTITATIVE DESCRIPTION OF CONFINEMENT

Depth (ft)	Degree of Confinement*	Thickness (ft)
1,310-1,350	Poor	40
1,350-1,420	Moderate	70
1,420-1,440	Poor	20
1,440-1,770	Moderate	330
1,770-1,930	Poor	160
1,930-2,020	Moderate	90
2,020-2,290	Good	270
2,290-2,330	Poor	40
2,330-2,550	Good	220
2,550-TD	"Boulder Zone"	780

*The degree of confinement is listed as:

Poor = Vertical permeability greater than 100 md
Moderate = Vertical permeability between 5 and 99 md
Good = Vertical permeability less than 5 md

Adding the thickness of each degree of confinement above the Boulder Zone to 1,310 feet results in:

Poor Confinement = 260 feet
Moderate Confinement = 490 feet
Good Confinement = 490 feet

c:\wp-tabl5\09342TBW.E15

5.0 MECHANICAL INTEGRITY TESTING

Throughout the drilling of both the injection and monitor wells, construction and hydrogeologic data were collected and analyzed. These data were used as a basis for construction decisions such as casing depths and monitor zones and to assess the mechanical integrity of both wells.

Mechanical integrity of IW-1 was evaluated during construction through the following mechanical integrity tests (MIT):

1. Temperature logs of 20-inch casing, beginning October 3, 1992.
2. Cement bond log of the 20-inch casing, October 6, 1992.
3. Pressure test of the 20-inch casing, October 8, 1992.
4. Pressure test of annular space between the 20 and 16-inch casing, November 2, 1992.
5. Television survey of 20-inch casing and 16-inch casing and open hole, October 25, 1992 and November 4, 1992, respectively.
6. Injection test, beginning February 23, 1993.
7. Radioactive tracer survey (RTS), February 25, 1993.

Mechanical integrity of the dual completion deep monitor well (DMW-1) was evaluated during construction through the following MITs:

1. Temperature logs of 16-inch and 6-inch casings, beginning August 7, 1992 and October 6, 1992, respectively.
2. Cement bond log of 16-inch casing, August 13, 1992.
3. Pressure test of 16-inch casing, September 4, 1992.
4. Cement bond log of 6-inch casing, October 9, 1992.
5. Pressure test of 6-inch casing, October 12, 1992.

5.1 Injection Well No. 1 - MIT

Introduction

Mechanical integrity tests (MIT's) of the injection well included tests designed to analyze the integrity of the casing materials and the quality of the bond between the annular grout (cement) and the casings in the well. The first test performed was on the casing joint welds. An acoustic analyzer was run over each weld prior to the lowering of the casing into the well to verify that there were no gaps, hollows or weak points in the weld. Any welds that did not pass this test were ground out and re-welded prior to proceeding to the next joint.

After the lowering of the casing into the borehole, the next test in each series was a temperature log of the fresh cement job to verify both the presence of cement behind the casing and that an appropriate curing temperature was reached. The third MIT was the cement bond log (CBL), performed after the cement had cured, to assure that a satisfactory bond had been attained between the casing and the cement.

The fourth test, the casing pressure test, verified the structural integrity of the casing itself, insuring that there were no leaks in the casing or the welded joints. A TV survey was performed as the fifth MIT, allowing for a visual inspection of the inside of the injection casing.

Operational testing in the form of an 24-hour, 6.2 million gallon injection test was the sixth MIT, verifying that the well would accept anticipated rates of injection. The seventh and final test was a radioactive tracer survey (RTS) that was performed to verify that injected fluid could not migrate upward behind the well casing. These tests, all of which were witnessed by Missimer Division personnel and were judged to have been satisfactorily completed, are described in detail below.

5.1.1 Temperature Logs

The second MIT's conducted on the injection well were the temperature logs run on each successive cementing stage. A summary of cementing operations showing the number of stages for each cementing operation is presented in Table 3.

As the cement emplaced in the annulus between the casing and the formation cures, it generates heat. If curing proceeds too rapidly the temperature will "flash", resulting in a spike on the temperature log. Conversely, a significant drop in temperature across a section of casing can indicate a void in the cement. All of the temperature log MIT's confirmed the presence of sufficient cement and that the appropriate curing temperature was maintained in the cement behind the casing strings. These logs may be found in Appendix I.

5.1.2 Cement Bond Logs

Introduction

The cement bond log (CBL) is a geophysical log used to evaluate the quality of the bond between the casing and the cement grout and between the cement and the formation. The CBL is an acoustic log which provides a relative measure of the amount of the cement behind the casing and the degree of bonding between the casing, the cement, and the formation.

The CBL is performed by lowering the logging tool down the hole while transmitting an acoustic signal from the tool outward toward the casing wall. This signal penetrates the casing, cement, and formation and is reflected back to a receiver in the logging tool. The signal is then recorded by the logging instrumentation and various qualities of the signal are displayed on the printout of the log.

Travel time

Travel time is a measure of the time that it takes for the signal to travel from the transmitter, through the casing fluid, casing, cement and formation, and back to the receiver. The primary usefulness of travel time is as an indicator of the centralization of the tool within the casing. Constant tool centralization is vital to the value of the log, as a tool that does not remain centered in the casing will produce an erratic response, rendering the log useless for evaluating cement fill and bond. A properly centered tool will be indicated by a relatively straight travel time log with only minor deviations at casing joint locations.

Amplitude

The amplitude of the acoustic signal is a measurement of the energy lost by the signal as it passes through the steel casing into the cement grout. The rate of this attenuation is dependant upon the percent of bonded cement, the casing diameter, and the thickness of the casing wall. A casing section that is totally un-cemented and in contact with formation fluid or drilling mud will cause the attenuation rate to be very small, and the returning amplitude will be relatively high. In a casing section that is well bonded to the cement grout, the wave velocity difference between the steel casing and the cement grout will cause significant attenuation of the acoustic signal and the returning amplitude will be relatively low. A properly centered tool, therefore, will allow for a direct correlation between the amplitude response and the amount of cement bonded to the outer casing wall, as well as the quality of the bond.

Total Energy Display

The third portion of the CBL is the total energy display, which is displayed as a variable density waveform log (VDL). The VDL is produced from the arrivals of the acoustic waves at a receiver spaced approximately five feet below the primary receiver on the logging tool. The VDL is used to qualitatively assess the bond between the cement and the formation and to detect the presence of channels in the cement grout which would allow injected fluid to migrate behind the casing wall. In order to make this assessment, the signature of the casing joints, represented on the log as W-shaped "chevron" patterns, are examined. In an un-cemented casing section this pattern is clear, while in well-cemented casing the pattern is barely discernable.

Summary and Evaluation of 20-inch Injection Casing CBL

On 6 October, 1992, a Cement Bond Log (CBL) was performed by Florida Geophysical Services on the 20-inch injection casing from 2475 feet to 50 feet below pad level (bpl). The logging operation was witnessed by Gordon Kennedy (Missimer Division) and was done prior to topping off with the last stage of cement in order to get a background reading on the free pipe above the next-to-last stage (0-200 feet bpl). This log may be found in Appendix I.

The critical transit time log, which validates the rest of the log, is found on the left side of the log chart. The transit times displayed on this log plot as a nearly straight line on the log. The greatest deviations on the log never exceed 100 microseconds, and these zones all appear to correlate with changes in the density of the formation (interbedded dense dolomites and cavernous limestones, for example). Overall, the log indicates adequate tool centralization, allowing for a valid evaluation of the amplitude curve.

The casing signal amplitude curve is presented in the middle track of the CBL, with the VDL to the far right of the chart. The amplitude and VDL indicate a well bonded casing throughout the entire run of the log, with minor deviations again correlating to geologic heterogeneity. The free pipe section of 50 to 200 feet bpl displays amplitudes of approximately 75 millivolts (mV), while the reminder of the log never exceeds 50 mV and averages about 25 mV.

The bond between the cement grout and the formation, as represented by the VDL, was also interpreted as being satisfactory, due to the minimal perturbations in the VDL. The casing joint signals, distinctly evident in the un-cemented section of casing, are minor below 200 feet bpl. The cementing program carried out on this well was evidently thorough enough to allow the cement to bond well to the entire borehole wall and to cure with minimal separation.

In summary, the cement bond log run on the 20-inch injection casing strongly indicates a well cemented casing that meets the standards set forth in FAC 17-28.

5.1.3 Pressure Tests

Pressure testing was performed on the final casing strings of both the injection and monitor wells in order to evaluate the operational integrity of the casing and the joint welds. Test results are presented in Appendix H. The tests were conducted after the cement had cured while the bottom of the casing string was still sealed with cement. A wellhead was bolted to the top flange of the casing, and a pressure gauge and relief valve were fitted to the wellhead. Any air present in the casing was bled off to eliminate the effect of air compression and expansion. The casing was then pressurized with water and the pressure loss over the course of one hour was recorded.

On 8 October, 1992, a pressure test was performed on the recently cemented 20-inch steel casing. The test was witnessed by Buzz Walker and Gordon Kennedy (Missimer Division) and Rick Orth (FDEP). The casing was pressurized to 158 psi at the start of the test. After one hour the pressure had dropped to 150 psi, a change of approximately -5%. This was approved by Rick Orth and Buzz Walker, and the test was deemed a success.

On 2 November, 1992, a pressure test was performed on the annulus between the 16-inch injection tubing and the 20-inch casing. The annulus had been filled with Baracor 100, a corrosion and bacterial inhibitant, and was sealed at the bottom by the TIW O-ring seal packer. The test was witnessed by Cliff Harrison (Missimer Division) and Jack Myers (FDEP). The starting pressure for the test was 158 psi, and after one hour no pressure had been lost. The annular space was therefore judged to be free from leaks.

5.1.4 Television Survey

On 25 October, 1992, a television survey was conducted by Florida Geophysical Services on the 20-inch casing and the open hole from 100 feet to 2850 feet bpl. Jackie Breland (Missimer Division) witnessed the test. From 100 feet to 2500 feet bpl (the bottom of the cement at the casing seat) the casing was shown to be intact and free from visible defects. From 2500 feet to 2560 feet bpl the open hole was dense and fractured with a 4-foot thick porous zone from 2530-2534 feet bpl. Between 2560 and 2582 feet bpl the hole walls were porous with large cavities and fractures present. From 2582 feet bpl to the total depth of the logging run the formation was dense, blocky, and fractured, with common large cavities and cavernous zones becoming more frequent and well developed with depth. At 2830 feet bpl the water in the borehole had become so murky as to preclude any further video logging.

On 4 November, 1992, a final television survey was made of the well, running from 10 feet to 2580 feet bpl with Buzz Walker and Cliff Harrison (Missimer Division) witnessing. Down to 2450 feet bpl, the depth at which the TIW packer was set, the 16-inch injection liner appeared smooth and free from defects. Below this point the survey was re-examining the section that had been logged on 25 October, 1992, and the results were similar. At 2580 feet bpl the logging operation was suspended due to murky water.

The television surveys of the 20-inch casing and the 16-inch injection liner showed no evidence of defects in the material or welds. The open portion of the borehole showed well developed cavernous zones below approximately 2582 feet bpl.

5.1.5 Injection Test

On 23 February, 1993, a constant rate injection test was performed on IW-1 (CO-2317) in order to evaluate the hydraulic characteristics of the well and injection zone. During a constant rate injection test, the system is tested by pumping fluid into the injection zone at a rate equal to or higher than the expected normal operating rate. This rate is maintained throughout the injection phase of the test.

Prior to the test, data control points are established within the system to monitor the effects of injection on the injection well and the monitor well zones. Typically, these control points will include wellhead pressure, injection zone pressure and temperature, and monitor well pressure in both zones. Control points outside the injection system are also established and subsequently monitored in order to determine the nature and extent of variable influences other than injection on the system. Outside control points commonly used include barometric pressure and local tidal fluctuations (when near tidally influenced waters). Data is collected from each of the points prior to the test, during injection and after injection to determine the rate of recovery. Those data collected prior to the test establish background conditions, against which the injection and recovery data are compared.

The NCRWTP injection test consisted of a 24-hour background data collection phase, a 24-hour constant rate injection phase, and a 12-hour recovery phase. The injection rate for the test was approximately 6.2 million gallons per day, or about 4300 gallons per minute (gpm). The water was delivered to the well by a temporary 16-inch polyvinyl pipeline connected to the Collier County potable water main located approximately one-half mile from the well site. The injection rate was achieved with the use of two diesel pumps adjacent to the well site. The rate was continually monitored via a totalizing flowmeter (Flowmeter #1) located immediately up-flow from the wellhead and the rate maintained by throttling the pumps up or down as necessary.

The injection rate was verified through periodic monitoring of the totalizing flowmeter at the tie-in point with the county's water main (Flowmeter #2). The flow rate had to be adjusted three times during the test to compensate for reduced/increased pressures in the county's water main that were related to system-wide water demands.

Data control points within the system were maintained at the aforementioned flowmeters, the injection well and the monitor well with the use of pressure transducers and pressure gauges. A summary of all data collection points and methods is provided in Table 15. All pressure gauge, flow rate, and barometric pressure data were recorded by hand. Pressure transducers connected to data loggers were installed at the injection well wellhead, injection well annulus, injection

TABLE 15
INJECTION TEST MONITORED PARAMETERS

CONTROL POINT/ ZONE MONITORED	PARAMETER(S) MONITORED	COLLECTION METHOD(S)
Injection Well IW-1 Wellhead	Pressure	- 100 psi transducer - 100 psi gauge
Injection Well IW-1 Annulus	Pressure Temperature	- 1500 psi transducer (temp & press) - 300 psi gauge
Injection Well IW-1 Bottom-hole	Pressure Temperature	- 5000 psi transducer (temp & press)
Monitor Well Upper Zone	Pressure	- 30 psi transducer - 30 psi gauge
Monitor Well Lower Zone	Pressure	- 30 psi transducer
Barometric Pressure	Atmospheric pressure	- Manually read barometer
Tidal Cycle	Gravitational fluctuations of water level	- NOAA tide tables
Flowmeter 1 (Wellhead Injection Line)	Injection rate and total fluid injected	- Manually calculated flow and total from totalizing meter
Flowmeter 2 (Water Main Tie-in)	Injection rate and total fluid injected	- Manually calculated flow and total from totalizing meter

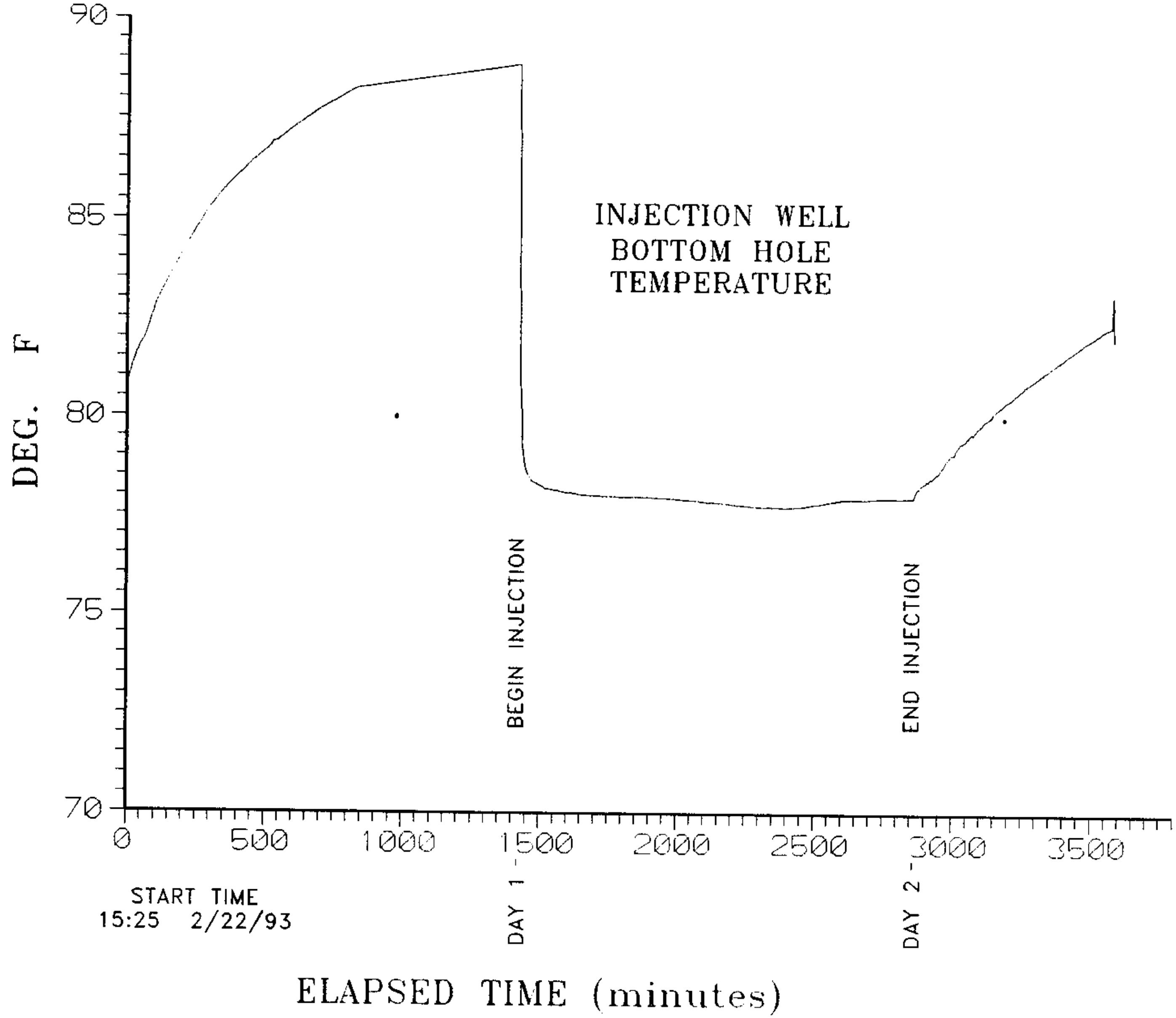
zone, and upper and lower monitor zones. The annulus and injection zone transducers recorded temperature as well.

Prior to the background monitoring period, a short (110,000 gallons in 33 minutes) injection test was performed to verify the efficiency of the pumps. Recovery from this test is evidenced by the increase in bottom hole temperature from 80.8 to 88.3 degrees Fahrenheit as the cool injected water was warmed by formation water during the background period (see Figure 8). Bottom hole pressure, as shown in Figure 9, increased very gradually from 1121.3 to 1122.4 psi during this period, indicating that the test injection did not significantly stress the injection zone. Wellhead pressure remained very stable at about 39 psi during the injection period; the negative deviations in wellhead pressure observed in Figure 10 during the background and injection periods reflect recording by the data logger at times when water was being bled off of the wellhead to pressurize the annulus.

Annular pressures depicted in Figure 11 appear to fluctuate drastically in the early part of the background period; this is due to activities associated with sealing off the transducer cable packer while the transducer housing was valved off from the annulus. Once the cable packer was sealed, the annulus was pressurized to 112 psi, after which it steadily gained pressure throughout the background period due to the temperature increase of the injected water as mentioned above.

During the injection phase of this test, the annulus required repressurization at an increasing rate. The cause of these pressure losses during injection is not known at this time, but it is suspected that a leak in the pressure recording system may have been responsible for the pressure drops.

The upper and lower monitor zones displayed unexpected patterns during the entire test. Water level fluctuations in both of these zones were expected to follow a



ViroGroup

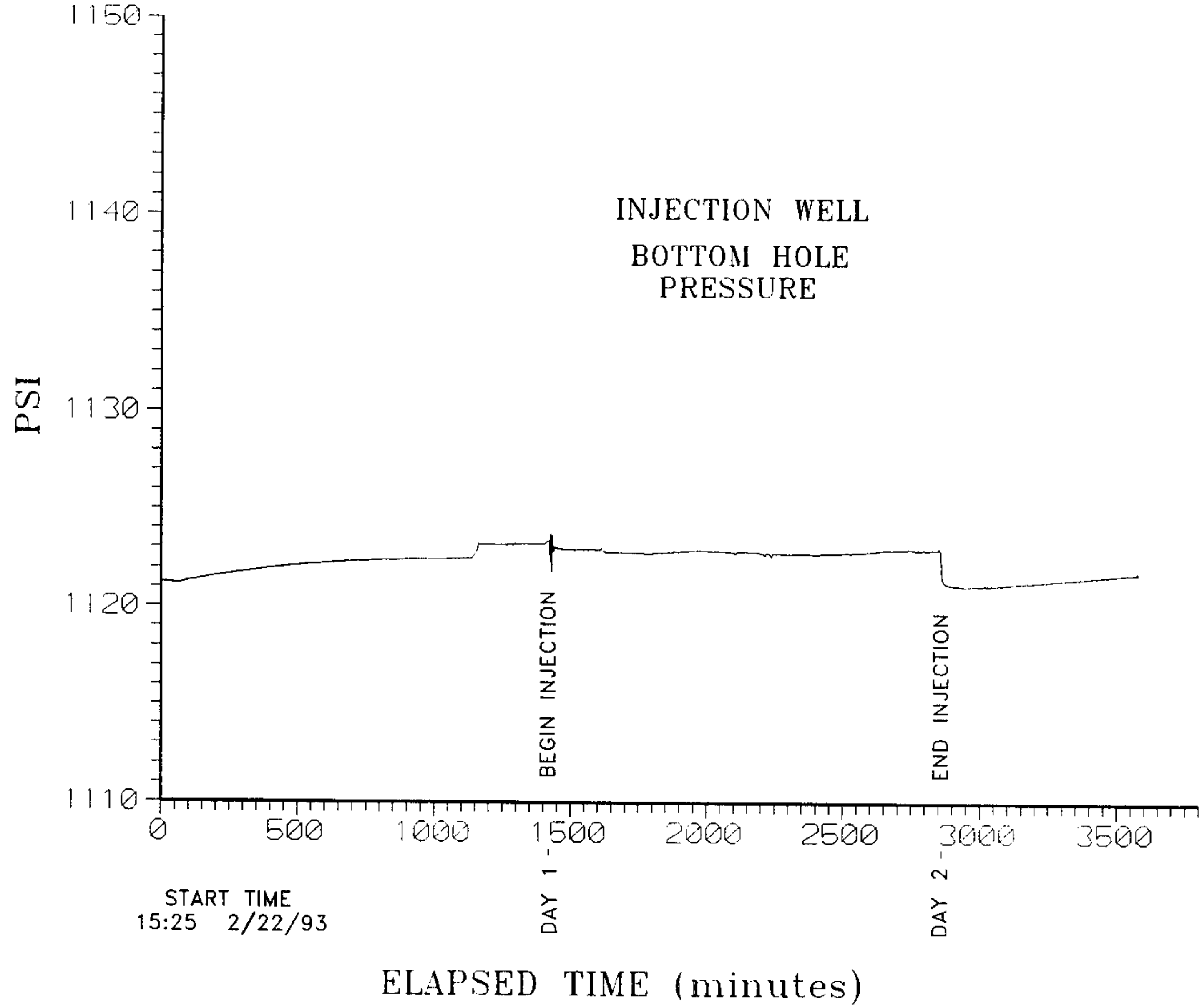
AIR • WATER • SOIL TECHNOLOGY

DRN. BY: CAM DWG NO. A-019342ED-4 DATE: 8/19/93

PROJECT NAME: COLLIER COUNTY DEEP PROJECT NUMBER: 01-09342.05

MISSIMER DIVISION

FIGURE 8. INJECTION TEST; INJECTION WELL BOTTOM HOLE TEMPERATURE.

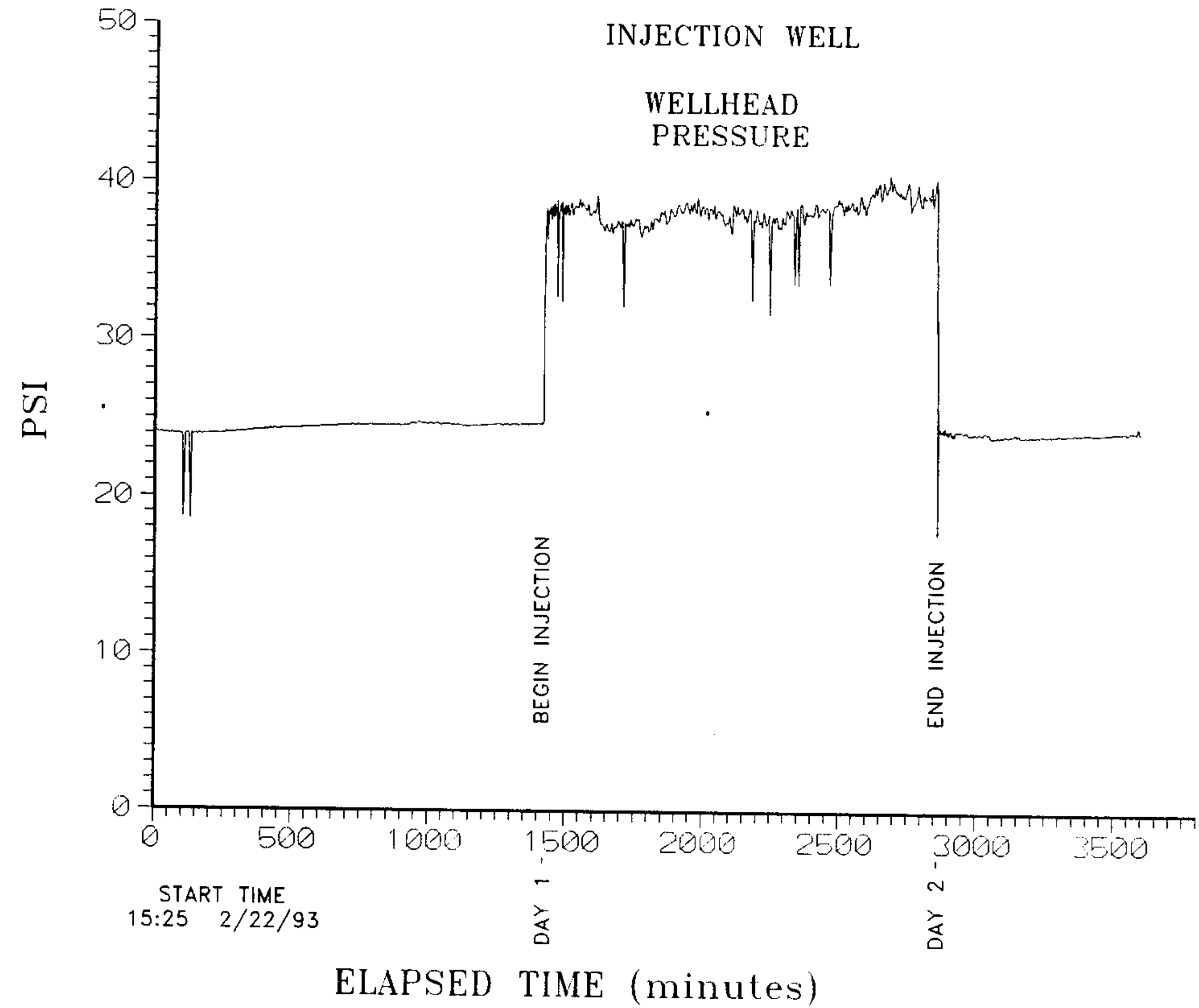


ViroGroup | AIR • WATER • SOIL TECHNOLOGY | MISSIMER DIVISION

DRN. BY: CAM DWG NO. A-019342EC-3 DATE: 8/18/93

PROJECT NAME: COLLIER COUNTY DEEP PROJECT NUMBER: 01-09342.05

FIGURE 9. INJECTION TEST; INJECTION WELL BOTTOM HOLE PRESSURE.



ViroGroup

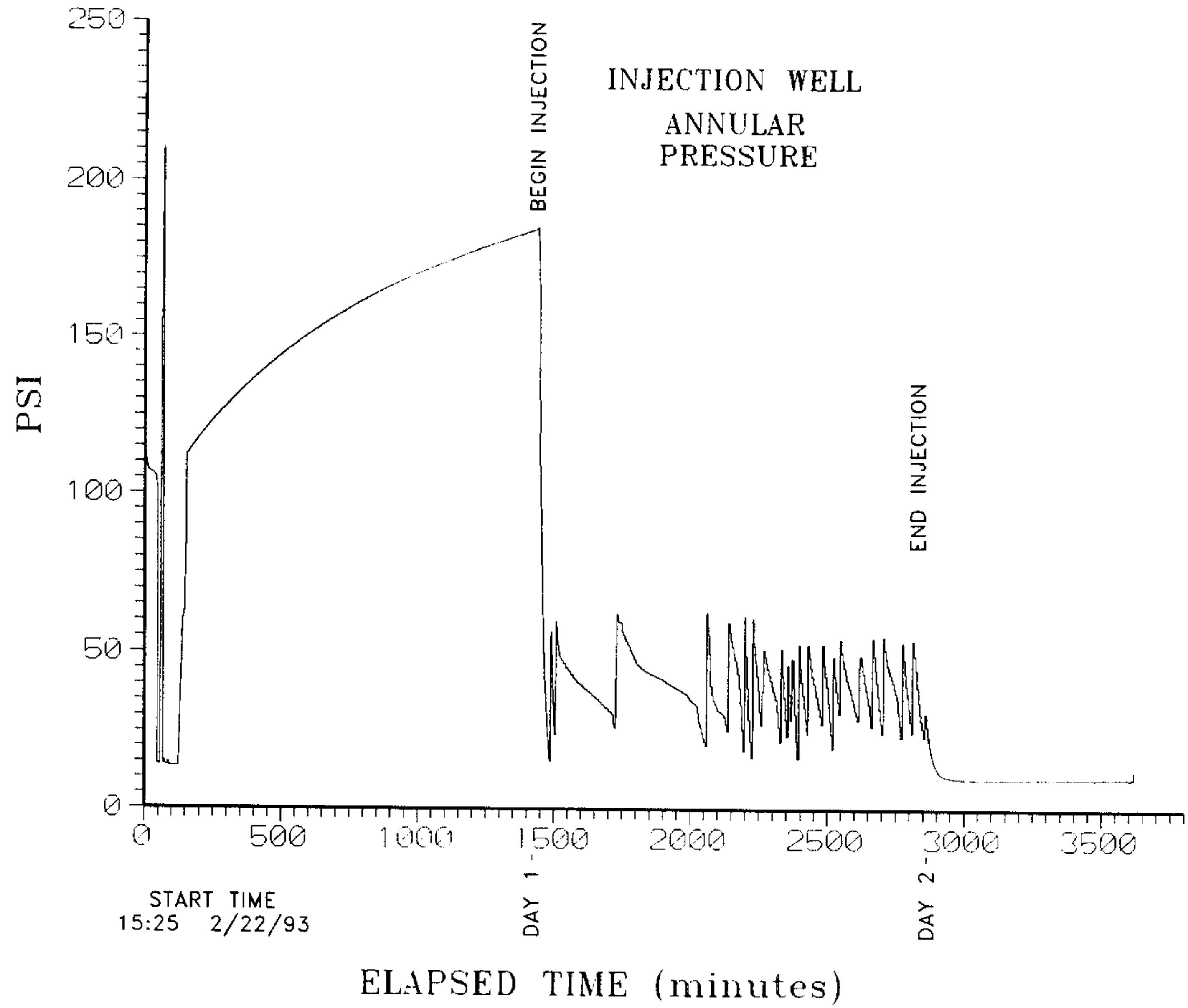
AIR • WATER • SOIL TECHNOLOGY

DRN. BY: CAM DWG NO. A-019342EL-4 DATE: 8/19/93

PROJECT NAME: COLLIER COUNTY DEEP PROJECT NUMBER: 01-09342.05

MISSIMER DIVISION

FIGURE 10. INJECTION TEST; WELLHEAD PRESSURE.



ViroGroup

AIR • WATER • SOIL TECHNOLOGY

DRN. BY: CAM DWG NO. A-019342EA-3 DATE: 8/18/93

PROJECT NAME: COLLIER COUNTY DEEP PROJECT NUMBER: 01-09342.05

MISSIMER DIVISION

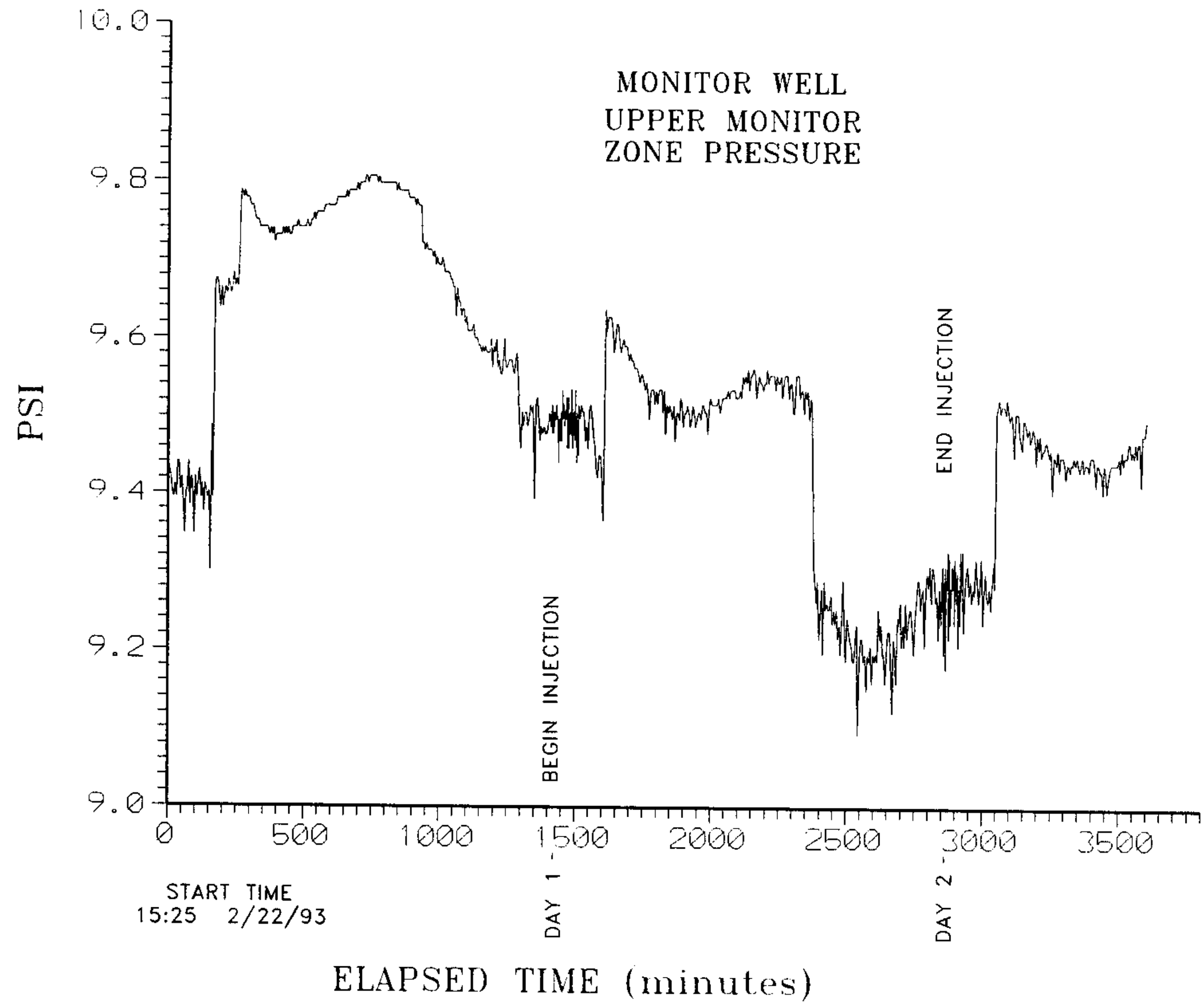
FIGURE 11. INJECTION TEST; INJECTION WELL ANNULAR PRESSURE.

sinuous pattern in response to tidal fluctuations. However, the patterns in the two zones were almost exactly opposite one another, and the fluctuations followed a step-wise pattern. The pressure curves, depicted in Figures 12 and 13, not only display virtually instantaneous changes in pressure at the points where the steps occur, but also appear very erratic and "noisy", not smooth as would be expected had they been the result of natural causes.

The relationship between the tidal cycle and tidal fluctuations in coastal aquifers are governed by the aquifer's storativity, transmissivity, and the distance between the well and the sub-oceanic outcrop of the aquifer. There is usually a time lag between the peaks in amplitude of the tidal cycle and those of the aquifer fluctuations. This time lag and the amplitude of the observed fluctuations are controlled by the aforementioned parameters, but the general pattern can be expected to parallel the tidal cycle. This was not the case in the data collected during the injection test.

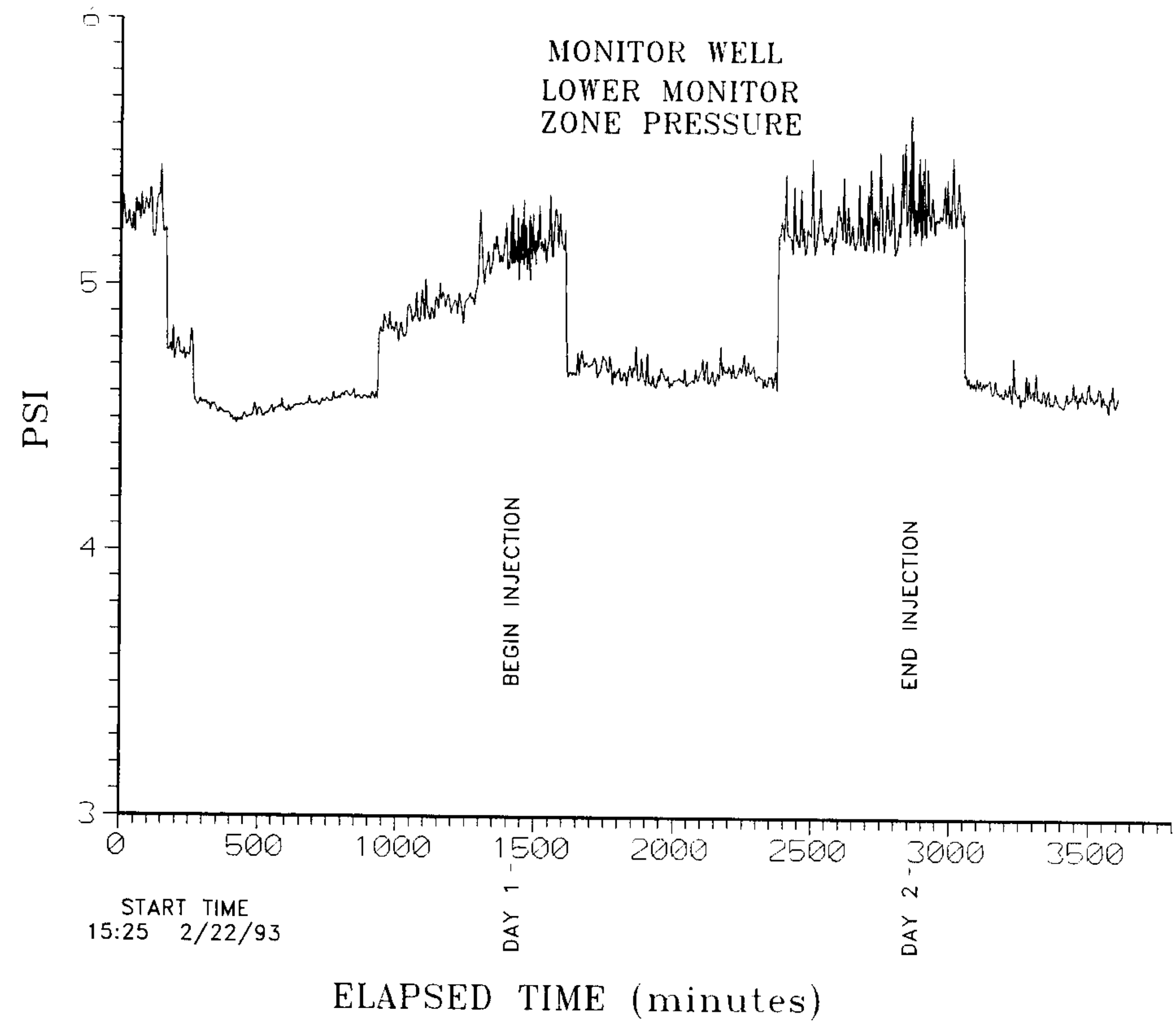
When compared to the tidal chart, shown in Figure 14, prepared with hourly tide levels at Naples, FL (approximately 10 miles southwest of the NCRWTP site), there does not appear to be any significant correlation between the recorded pressure values and the tidal cycle. It is evident, however, that there is a degree of negative correlation between the values recorded for each of the two monitor zones. The steps on each graph occur at the same time, but in opposite directions; when one graph steps up, the other steps down.

In an attempt to isolate the source of these erratic patterns the geophysical logging company that performed the test, Florida Geophysical Logging, Inc., was contacted on 18 March, 1993 and presented with the graphs of the data from the two monitor zones and of the Naples tidal cycle for the period of the test. This and all other correspondence may be found in Appendix B. Florida Geophysical responded on 21 March, 1993 that they had no idea why the data produced these unexpected



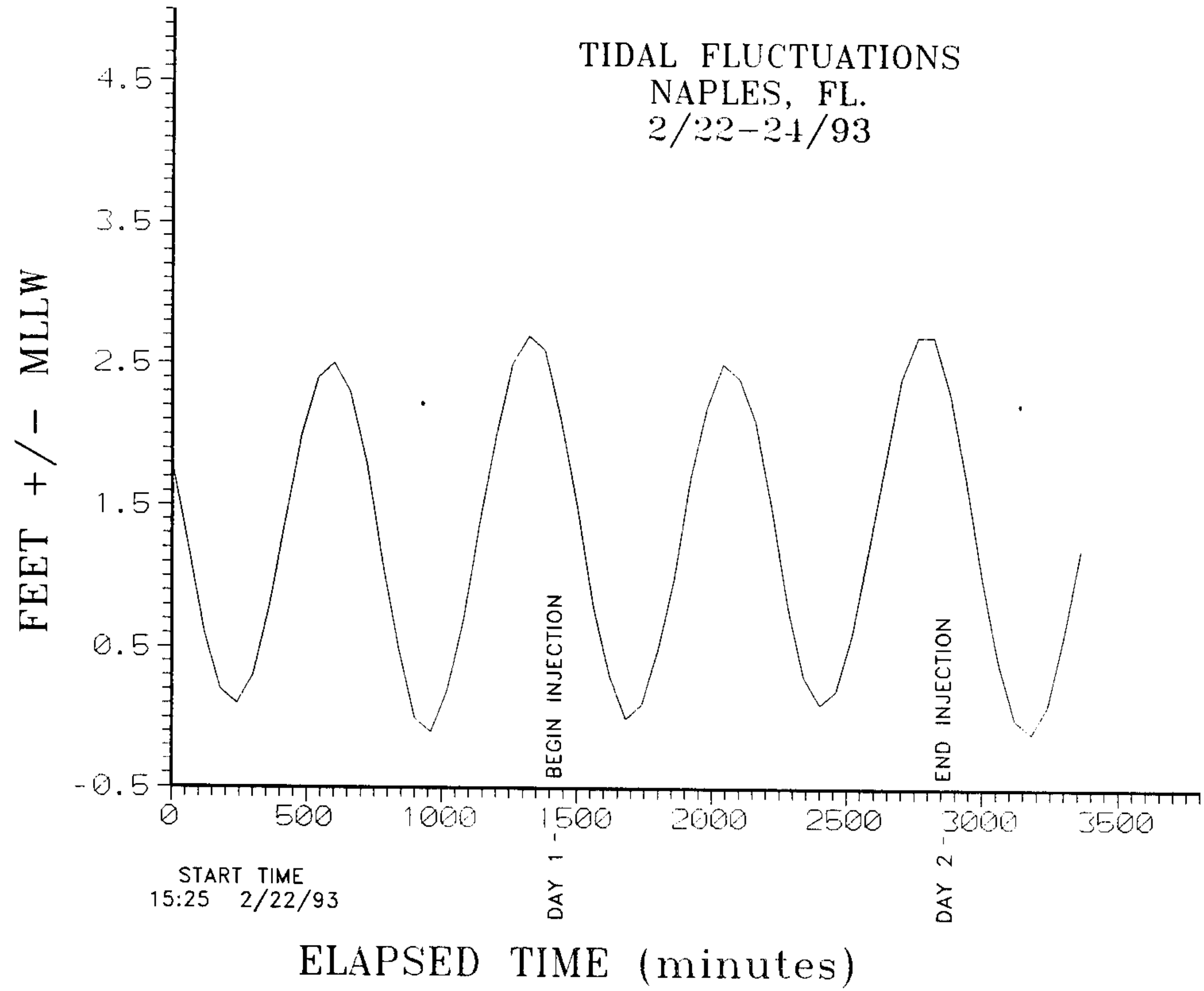
ViroGroup	AIR • WATER • SOIL TECHNOLOGY DRN. BY: CAM DWG NO. A-019342EH-3 DATE: 8/18/93 PROJECT NAME: COLLIER COUNTY DEEP PROJECT NUMBER: 01-09342.05	MISSIMER DIVISION

FIGURE 12. INJECTION TEST; MONITOR WELL UPPER MONITOR ZONE PRESSURE.



ViroGroup	AIR • WATER • SOIL TECHNOLOGY	MISSIMER DIVISION
	DRN. BY: CAM DWG NO. A-019342EF-3 DATE: 8/18/93	
	PROJECT NAME: COLLIER COUNTY DEEP PROJECT NUMBER: 01-09342.05	

FIGURE 13. INJECTION TEST; MONITOR WELL LOWER MONITOR ZONE PRESSURE.

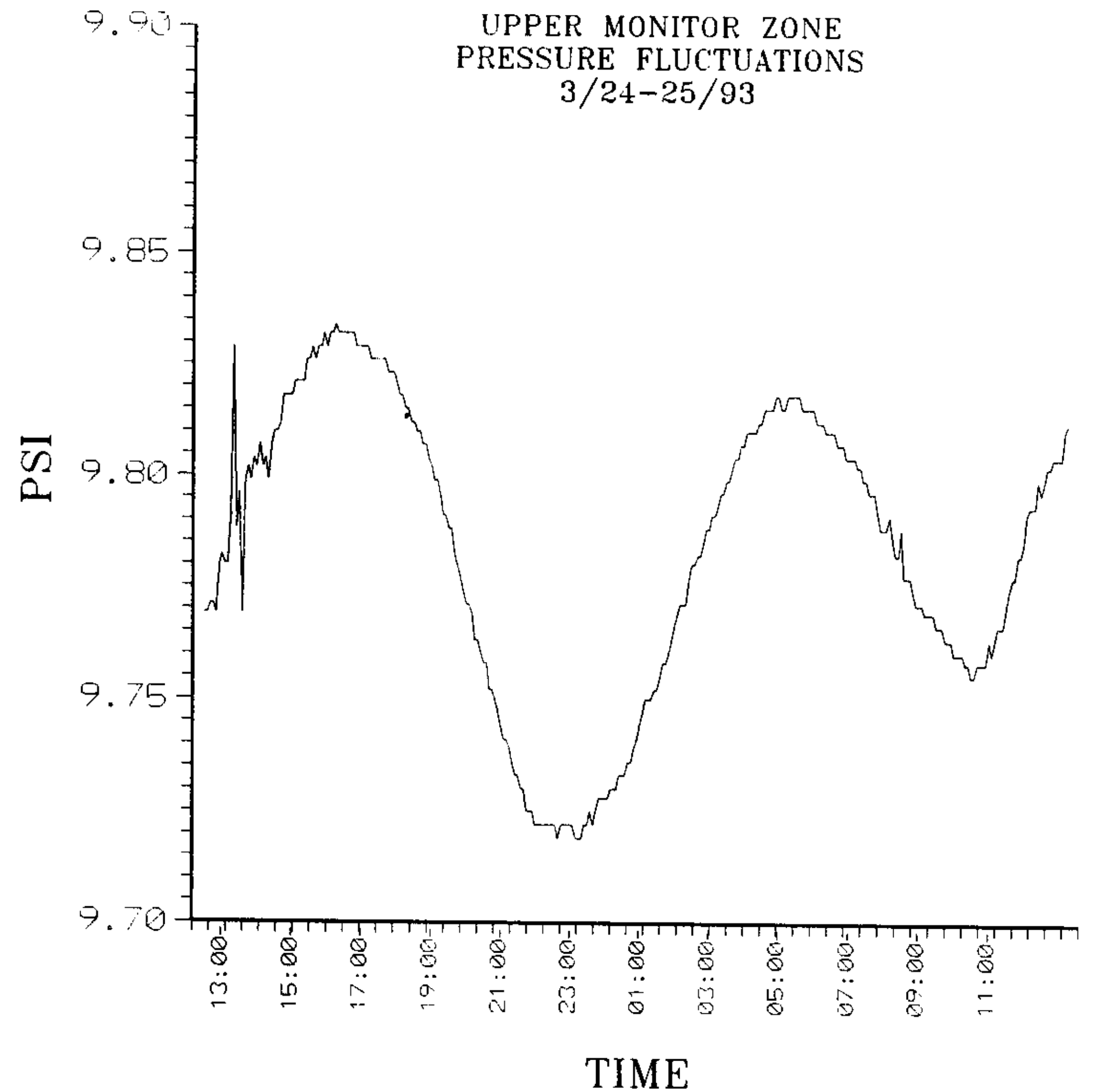


ViroGroup	AIR • WATER • SOIL TECHNOLOGY	MISSIMER DIVISION
	DRN. BY: CAM DWG NO. A-019342EJ-4 DATE: 8/19/93	
	PROJECT NAME: COLLIER COUNTY DEEP PROJECT NUMBER: 01-09342.05	

FIGURE 14. INJECTION TEST; TIDAL FLUCTUATIONS, NAPLES, FLORIDA (2/22-24/93).

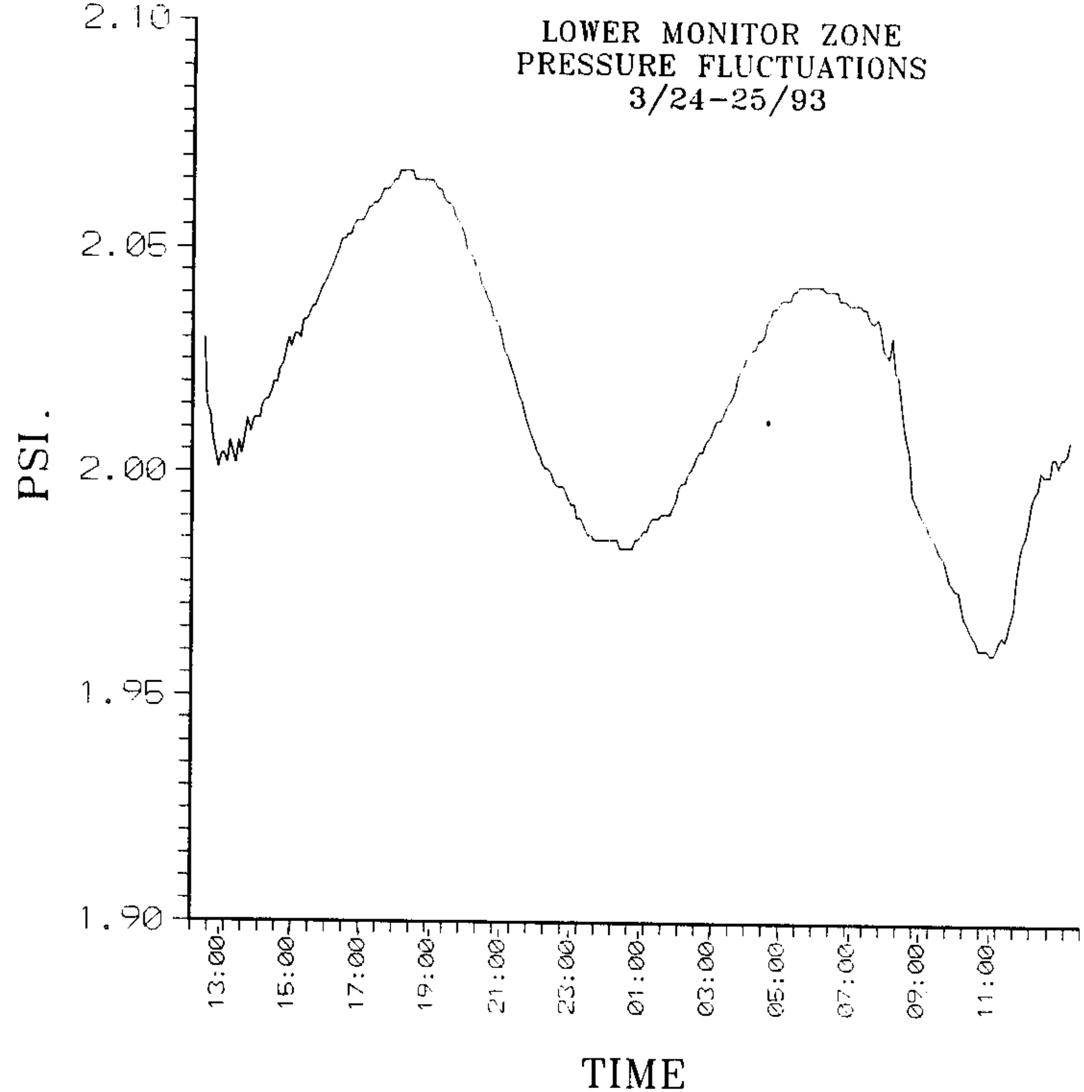
results, but agreed to contact the manufacturer of the data logger in an attempt to clarify the situation. Meanwhile, Missimer Division personnel recorded pressures in both monitor zones with a different transducer and data logger array for 24 hours between 24 March and 25 March, 1993. The patterns resulting from these data (see Figures 15-17) were similar to what would be expected in a coastal aquifer: the highs and lows on the monitor well graphs paralleled each other with a lag of about two hours, and also paralleled the tidal graph for that period with a lag of three to four hours. While the injection test situation was not exactly duplicated as no fluid was being injected into IW-1 during this time, it was concluded that normal tidal fluctuations do occur in both monitor zones, and that the data collected from these zones during the injection test were not valid.

At this point, Florida Geophysical was attempting to contact Instrumentation Northwest, the vendor for the rented pressure transducer equipment used during the injection test. The vendor finally responded to Florida Geophysical's inquiries in May, at which time the conclusion was reached that there was nothing wrong with the procedure followed by Florida Geophysical in setting up the equipment. Instrumentation Northwest did admit that the problem might have been caused by "mechanical stickage" in the transducers. Florida Geophysical expressed doubts about this assessment, pointing out that both transducers in the monitor well displayed the same patterns at exactly the same times, albeit in a negative relationship to each other. The feeling that Florida Geophysical had was that the common link between the transducers, the data recording device, was the source of the problem. This assessment was neither supported nor denied by Instrumentation Northwest. These conversations and conclusions are documented in a letter from Florida Geophysical in the correspondence section, Appendix B.



ViroGroup	AIR • WATER • SOIL TECHNOLOGY	MISSIMER DIVISION
	DRN. BY: CAM DWG NO. A-019342EK-3 DATE: 8-19/93	
	PROJECT NAME: COLLIER COUNTY DEEP PROJECT NUMBER: 01-09342.05	

FIGURE 15. CALIBRATION TEST; UPPER MONITOR ZONE PRESSURE FLUCTUATIONS (3/24-25/93).



ViroGroup

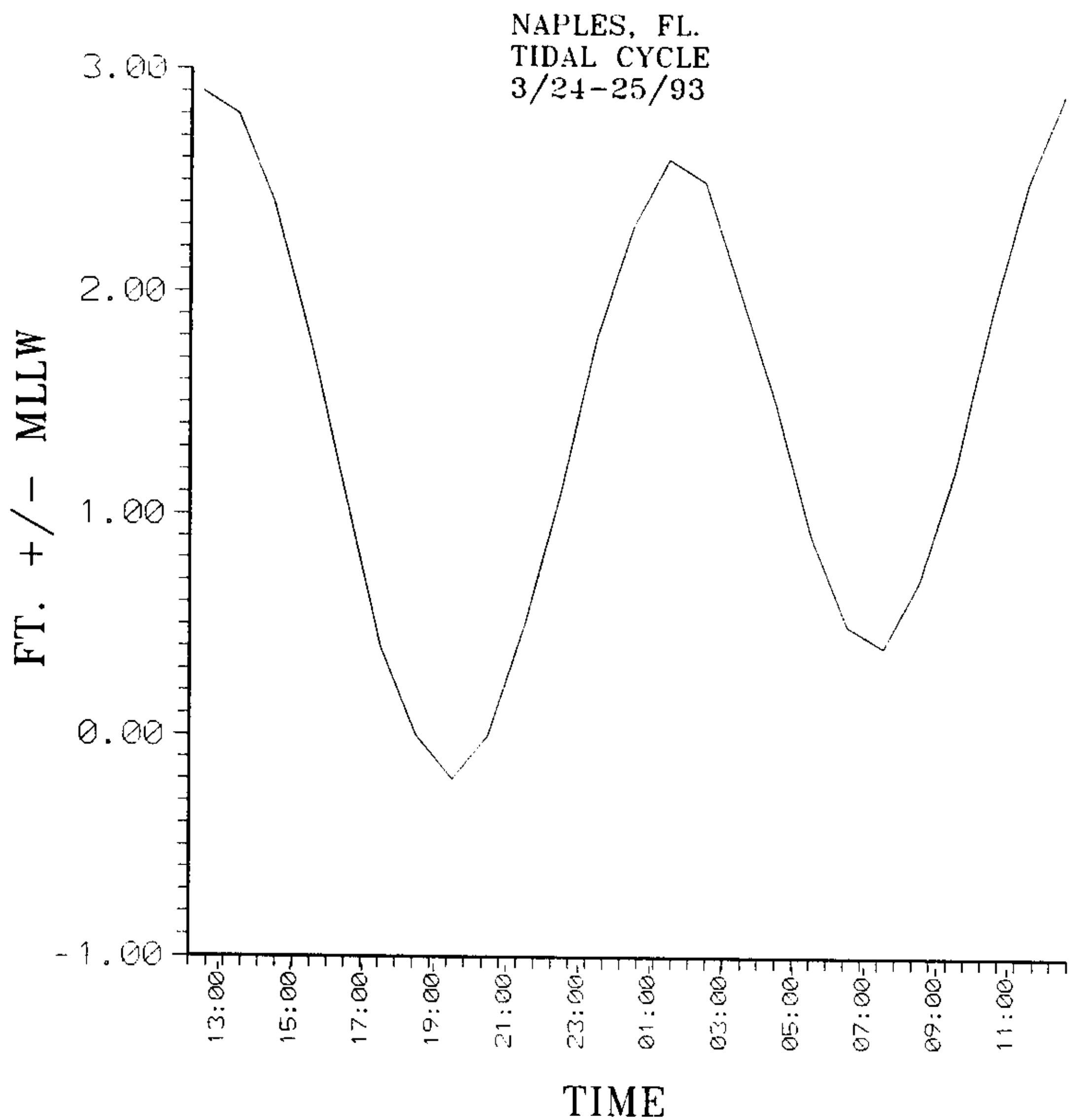
AIR • WATER • SOIL TECHNOLOGY

DRN. BY: CAM DWG NO. A-019342EE-3 DATE: 8/19/93

PROJECT NAME: COLLIER COUNTY DEEP PROJECT NUMBER: 01-09342.05

MISSIMER DIVISION

FIGURE 16. CALIBRATION TEST; LOWER MONITOR ZONE PRESSURE FLUCTUATIONS (3/24-25/93).



ViroGroup	AIR • WATER • SOIL TECHNOLOGY	MISSIMER DIVISION
	DRN. BY: CAM DWG NO. A-019342EI-2 DATE: 8/18/93	
	PROJECT NAME: COLLIER COUNTY DEEP PROJECT NUMBER: 01-02342.05	

FIGURE 17. CALIBRATION TEST; NAPLES, FLORIDA TIDAL CYCLE (3/24-25/93).

5.1.6 Radioactive Tracer Survey

A Radioactive Tracer Survey, or RTS, was conducted on IW-1 on February 25, 1993, by Florida Geophysical Logging, Inc. This test was witnessed by Joe Haberfeld, Vince Mele, and Rick Orth (FDEP), and Gordon Kennedy and Cliff Harrison (Missimer Division). A copy of the RTS results is included in Appendix I. The survey was performed under both static and dynamic conditions to evaluate the integrity of the grout seal around the 20-inch casing and the packer seal below the 16-inch injection tubing. The integrity of these seals is critical in ensuring that no upward migration of injected fluid takes place. The results of the test performed on IW-1 indicated that no upward movement of the tracer behind the casing or tubing occurred. Two days prior to conducting the test, 6.2 million gallons of fresh water were pumped into the well over 24 hours for an injection test. This also served to create a fresh water bubble within which to perform the RTS. The procedure for the radioactive tracer survey was as follows:

1. Ran temperature log from land surface to 2720 feet below land surface (bls).
2. Ran background gamma ray log.
3. Located bottom of casing at 2,488 feet bls with casing collar locator (CCL).
4. Performed Static Radioactive Tracer Survey. Ejector/detector tool was equipped with the iodine ejector and gamma ray detectors at the following distances from the bottom of the tool: bottom gamma ray detector (GRB) - 6 inches; casing collar locator (CCL) - 9 feet; middle gamma ray detector (GRM) - 10.5 feet; ejector - 13 feet; top gamma ray detector (GRT) - 23 feet.

4a. Positioned tool with ejector one foot below bottom of 20-inch casing (2,489 feet bls).

4b. Released first slug of tracer (2 millicuries Iodine-131), keeping tool stationary in time-drive recording mode while monitoring gamma ray detectors for 60 minutes. Gamma ray activity detected in upper gamma ray detector (GRT) after 12 minutes. Gamma ray activity detected in middle gamma ray detector (GRM) after approximately 14 minutes. Activity detection attributed to dispersion of tracer slug.

4c. Logged out of position up to 2,350 feet bls.

4d. Flushed with fresh water for 14 minutes at 2,063 gallons per minute (gpm). Total flush = 28,000 gallons; casing volume = 23,000 gallons.

4e. Repeated log from 2,505 feet bls to 2,350 feet bls and compared to background log. Tracer stain detected at 2,489 feet bls.

5. Performed Low Flow Rate Dynamic RTS on 20-inch casing.

5a. Positioned tool with ejector five feet above bottom of 20-inch casing (2,483 feet bls) and began injecting fresh water into well at 73 gpm.

5b. Released tracer slug #2 (2 millicuries Iodine-131), keeping tool stationary in time-drive recording mode while monitoring gamma ray detectors for 31 minutes. Gamma ray activity detected by GRM within approximately 30 seconds; activity dropped off within approximately 5 minutes as tracer slug passed GRM. Gamma ray activity detected by bottom gamma ray detector (GRB) after approximately 2 minutes; activity dropped off within approximately 6.5 minutes as tracer slug passed GRB.

5c. Logged out of position to 2,326 feet bls. Detected tracer stain at 2,483 feet bls.

5d. Flushed with fresh water for 22 minutes at 2,000 gallons per minute (gpm). Total flush = 42,000 gallons.

5e. Repeated log from 2,496 feet bls to 2,345 feet bls and compared to background log. Tracer stain detected at 2,486 feet bls.

6. Performed repeat Low Flow Rate Dynamic RTS on 20-inch casing.

6a. Positioned tool with ejector five feet above bottom of 20-inch casing (2,483 feet bls) and began injecting fresh water into well at 73 gpm.

6b. Released tracer slug #3 (2 millicuries Iodine-131), keeping tool stationary in time-drive recording mode while monitoring gamma ray detectors for 33 minutes. Gamma ray activity detected by GRM within approximately 30 seconds; activity dropped off within approximately 2 minutes as tracer slug passed GRM. Gamma ray activity detected by GRB after approximately 2 minutes; activity dropped off within approximately 7 minutes as tracer slug passed GRB.

6c. Logged out of position to 2,342 feet bls. Detected tracer stain at 2,480 feet bls.

6d. Flushed with fresh water for 16 minutes at approximately 2,000 gallons per minute (gpm). Total flush = 32,960 gallons.

6e. Repeated log from 2,502 feet bls to 2,344 feet bls and compared to background log. Tracer stain detected at 2,488 feet bls.

7. Performed Static Radioactive Tracer Survey.

7a. Positioned tool with ejector one foot below bottom of 20-inch casing (2,489 feet bls) for static test.

7b. Released tracer slug #4 (4 millicuries Iodine-131), keeping tool stationary in time-drive recording mode while monitoring gamma ray detectors for 64 minutes. Gamma ray activity detected by middle detector GRM within approximately 1.5 minutes. Gamma ray activity detected by GRB after approximately 22 minutes. Gamma ray activity detected by GRT after approximately 8 minutes.

7c. Logged out of position to 2,322 feet bls. Detected tracer stain from release point up to 2,466 feet bls, attributable to the large tracer slug being washed off of the tool.

7d. Flushed with fresh water for 13 minutes at approximately 2,000 gallons per minute (gpm). Total flush = 28,000 gallons.

7e. Lowered tool to 2,703 feet bls and logged to 1,478 feet bls and compared to background log. Tracer detected at 2,608 feet bls, within injection zone, indicating that tracer material had migrated downward to this zone. Tracer stain also detected at 2,490 feet bls, the site of the ejections.

To summarize, the results of the radioactive tracer survey indicate no upward migration of the tracer behind the 20-inch casing. The tracer did migrate up inside the casing during both of the static tests, but was also observed to migrate downward during the same tests, indicating that the migration was due to dispersal and not to directional migration behind the 16-inch tubing. The final log, run after a fresh-water flush of the well, detected tracer only in the injection zone and at the point of tracer release during the test, indicating that the well is performing satisfactorily with no migration behind either the tubing or the casing. The temperature log run at the start of the test indicates that the base of the fresh water bubble created during the injection test was at about 2660 feet bls. This indicates that only the upper portion of the injection zone was receiving injectate during the test.

5.2 Dual Zone Monitor Well - Mechanical Integrity Testing

5.2.1 Temperature Logs

Mechanical integrity testing of the dual zone monitor well began with the temperature logs run on the 16-inch diameter upper monitor zone casing beginning on 7 August, 1992, after each stage of cementing. A cementing summary showing the number of stages for each cementing operation is presented in Table 6.

Each of the temperature logs confirmed the presence of sufficient cement behind the casing and that the cement had cured at an appropriate temperature. These logs may be found in Appendix I. Temperature logs were also conducted on the cementing stages associated with the installation of the 6-5/8-inch diameter lower monitor zone casing beginning on 6 October, 1992. These logs were satisfactory, as well.

5.2.2 Cement Bond Logs

Following the cementing of the 16-inch upper monitor casing, a cement bond log (CBL) was run on 13 August, 1992 by Florida Geophysical Services. Gordon Kennedy (Missimer Division) was on site to witness this test. The CBL indicated a satisfactory bond between the casing, the cement grout, and the formation.

A CBL was also run on the 6-5/8-inch casing after it was cemented into place. The log was run on 9 October, 1992, and was witnessed by Cliff Harrison (Missimer Division). This log also indicated a sufficient grout job from the casing seat (1815 feet bpl) to the bottom of the upper monitor zone (990 feet bpl).

5.2.3 Pressure Tests

A pressure test (witnessed by Gordon Kennedy - Missimer Division and Rick Orth - FDEP) was conducted on the 16-inch upper monitor zone casing on 4 September, 1992, at a pressure of 154 psi. The pressure dropped 4 psi within one hour, for a 2.6% pressure loss, well within the allowable 5% drop.

Pressure testing was also performed on the 6-5/8-inch lower monitor zone casing on 12 October, 1992. Cliff Harrison (Missimer Division) and Vince Mele (FDEP) witnessed this test. The casing pressure gained 3 psi, or 2%, and was therefore successful.

5.3 MIT Summary and Conclusions

To summarize:

* All cement bond logs conducted on both the injection and monitor well casings indicated a sufficient bond between casing, cement, and formation.
* All pressure tests performed on both the injection well and the monitor well passed the FDEP permit requirements of a pressure change not in excess of +/- 5%.
* The television surveys of the injection well showed no abnormalities or defects in the 20-inch casing or the 16-inch injection tubing and packer. The open hole portion of the well remained free of obstructions to at least 2850 feet bpl, at which point the formation fluid was too cloudy to see the borehole walls.
* The radioactive tracer survey performed on the injection well indicated no upward migration of the tracer behind either the 20-inch or the 16-inch casing.
* The injection test showed that the injection zone is capable of accepting fluid at a rate of 4,300 gpm delivered at a wellhead pressure of 39 psi. The injection test also tentatively established that there is no communication between the injection zone and either of the monitor zones.

6.0 INJECTION WELL CONTROL AND MONITORING SYSTEMS

6.1 Concentrate Pump Station

(This section by Boyle Engineering Corporation)

6.1.1 General Description

The Concentrate Pump Station is a new facility constructed with the treatment plant and is located on the north side of the NCRWTP Process Building. The station receives the unchlorinated reject flows from the reverse osmosis (R.O.) membranes, the cleaning solution discharge from the membrane cleaning system and the floor drains from the process trench and chemical handling areas. Spills in the chemical area are neutralized before being pumped to the Concentrate Pump Station.

The station consists of a below grade, epoxy coated wet well with three variable speed vertical turbine pumps regulated by redundant level probes in the wet well and control instrumentation. The pump motors are mounted on the pump discharge column heads in the pump room located on top of the wet well. The wet well is equipped with forced ventilation connected to the plant odor control system.

6.1.2 Wet Well

The wet well is a poured in place, below grade concrete structure that is sealed to allow controlled ventilation through the plant odor control system. An access hatch is provided outside of the pump room to allow maintenance of the wet well. The wet well has a capacity of 30,000 gallons and is coated with a chemical resistant epoxy coating.

6.1.3 Pumps and Piping

Three pumps are manifolded together in the pump room above the wet well and discharged through a 16-inch diameter fiberglass pipe to the injection well located in the northwest corner of the treatment plant site. The pumps are line shafted vertical turbine pumps with their discharge located above the pump room floor. The standard electric motors are mounted vertically on the pump discharge heads and are driven by variable frequency drives (VFD) located in the Process Building Motor Control Center. Each pump discharge is equipped with an air/vacuum valve, check valve and isolation butterfly valve. These valves serve to isolate the pumps from the injection pipeline and prevent back flow. Additionally, a 16-inch gate valve at the wellhead isolates the injection casing from the pipeline.

The pumps are Peerless Model 12MB-3, 75 horsepower. All three pumps have a rated capacity of 1000 gpm at 174 feet of head. Two pumps are required for normal operation, one pump is back-up. The pump station is designed to pump 1.33 MGD of concentrate flow produced by the 12 MGD membrane softening plant. The pump station will also pump low pressure side streams such as chemical bypass water, flush water and cleaning water. An estimated 8.5 MGD of concentrate flow will be produced at the future plant capacity of 20 MGD, assuming complete conversion to reverse osmosis processes operating at 70% recovery. When this increased disposal capacity is required, the pump station, injection pumps and motor control, and wet well will need to be modified, as well as a second injection well installed.

6.1.4 Pump Motor Controls

The operation of the concentrate pumps is controlled by a water level monitoring system in the Programmable Logic Controller (PLC). When the flow enters the wet well causing the water level to rise, the lead pump will be energized. The speed of the lead pump will be adjusted by the control system to maintain a constant level in the wet well. If the level of the wet well continues to rise as the lead pump is running at full speed, then the lag pump will be energized. The speed of both pumps will be adjusted as necessary to maintain the water level in the wet well.

As the water level declines in the wet well, the lag pump will be shut down when both pumps are running at low speed. After the lag pump is off, the speed of the lead pump will be adjusted by the control system to maintain the wet well level. All pumps will be shut down at a low level setting. High and low level alarms will sound in the control room.

6.1.5 Surge Control

The concentrate piping connects directly to the injection well. A six-inch air release/air vacuum valve (ARVV) is installed on the well head, with air release valves on the discharge piping of each of the concentrate pumps. The ARVV on the well head is sized based on hydraulic modeling to relieve surges caused by a sudden decrease in the flow velocity within the piping system which would be caused by the pumps stopping suddenly. The pumps are all equipped with VFD's, as described above. Therefore, they will normally start and stop slowly. A sudden power failure could, however, cause the pumps to stop suddenly. The ARVV on the wellhead will allow air into the line to prevent negative pressure in the injection well.

6.1.6 Electrical Service

The concentrate pumps operate on 480-volt, three phase, 60-hertz power. Power is provided from the treatment plant main power distribution system which includes emergency generators with sufficient capacity to run this facility during a power outage.

6.1.7 Concentrate Flow and Pressure Instrumentation and System Alarms

The concentrate flow rate is measured with a magnetic flow meter. The flow reading is indicated locally and transmitted to the control room where it is indicated on the computer and automatically recorded. The pressure on the injection line is monitored and recorded in the control room. Low and high injection pressure alarms and low flow alarms are monitored and indicated on the computer in the control room.

6.1.8 Annulus Pressure Monitoring System and Alarms

The annulus pressure control and monitoring system consists of a 500 gallon hydropnuematic tank and related instrumentation. Both the pressure in the tank and the liquid level in the tank are monitored, providing dual methods of confirming the annulus fluid system is not leaking. Tank fluid level is indicated locally and transmitted to the control room. The tank pressure is also transmitted to the control room and is recorded. Low and high fluid level and pressure alarms are monitored on the plant computer in the control room. Additional annulus fluid must be added manually. There is a compressed air line run to the injection well to provide air to pressurize the hydropnuematic tank and a water line for make-up water.

6.2 Monitoring Data Collection and Reporting

The Collier County Utilities staff will collect injection system monitoring data to provide a record of system performance. This record indicates the injection system performance and will substantiate decisions and recommendations to be made concerning system operation and future system expansions.

The monitoring data that will be collected from the injection system are listed in the monthly reporting forms. Plant operators are advised to review the most recent FDEP correspondence for possible updates to this section. All instrumentation used for injection system monitoring purposes will be calibrated on a semi-annual basis.

6.2.1 Monitoring Data Monthly Report

The data for the monitoring monthly report must be compiled daily from the injection flow meter recorder chart, the injection pressure recorder chart, and the two monitor zone pressure recorder charts from the dual-zone monitor well. The operator must send three copies of the monthly report along with the other treatment plant monthly forms to the FDEP Southwest District office in Fort Myers.

6.2.2 Monitor Well Water Quality Report

Water quality samples will be collected from the dual-zone monitoring well. These samples will be compared to the pre-injection water quality presented in the appendix to detect any changes that might be caused by the upward migration of injected concentrate. If concentrate were to migrate into the monitoring zones, the monthly water samples would show a freshening trend from background chloride and specific conductance values. Significant deviations from background water quality or water level values should be confirmed and reported to FDEP immediately.

Standard procedures to be followed for weekly and monthly monitor well sampling events include the following:

1. Monitor zones shall be sampled following evacuation of three (3) full casing volumes for each zone. The calculated casing volume of the deep monitor zone is 3,250 gallons. Assuming an average pumping rate of 10 gpm, the time

required to purge 3 casing volumes will be 975 minutes (16.3 hours). The calculated casing volume of the shallow monitor zone is 7,800 gallons. Assuming an average flow rate of 25 gpm, the time required to purge 3 casing volumes will be 936 minutes (15.6 hours).

2. The pumping rate of the lower monitor zone and the flow rate of the upper monitor zone shall be monitored during the evacuation procedure to determine the length of time required to evacuate three full casing volumes as listed in Item 1.

3. Water withdrawn from the well casings and formations shall be collected in the FRP basin adjacent to the dual-zone monitor well and pumped to the wet well for disposal in the injection well.

4. Water samples from both monitor zones shall be analyzed on a weekly basis for the following parameters: pH, Temperature, Conductivity, Chloride Concentration, and Total Dissolved Solids. Additionally, water samples from the deep monitoring zone shall be analyzed on a monthly basis for the following parameters: Fluorene, Gross Alpha, Radium 226, and Radium 228.

5. Monitor well water quality data shall be included in the operational report submitted to the appropriate FDEP offices on a monthly basis.

6.2.3 Specific Injectivity Test

Specific injectivity tests will be run on the injection well on a quarterly basis. This test evaluates the injection capacity of the well to detect any changes caused by plugging or other flow-restricting conditions. The test should be run as follows:

1. The automated wet well water level control system will be turned off and the wet well volume will be allowed to be increased to 20,000 gallons prior to initiating the test.

2. The operator will manually operate one injection pump at a rate of 1,000 gpm. Once the rate is established, the injection pressure at the pressure recorder located at the instrument panel on the drilling pad will be measured. The pump should be run until the pressure stabilizes (not more than 10 minutes).

3. The operator will manually engage the second pump and adjust the flow until a combined rate of 2,000 gpm is obtained. Once the rate is established, the injection pressure will be recorded.

4. Depending on the level of the wet well, the operator could start and adjust the flow of the third pump until a combined rate of 3,000 gpm is obtained. The injection pressure will be recorded as indicated above. The operator should establish a minimum of two flow rates and corresponding pressures for each specific injectivity test.

5. After the pumps are shut off and the pressure has stabilized, the operator will record the shut-in pressure from the circular chart and verify the measurement against the pressure indicator at the panel and at the pipeline to the well.

6. The specific injectivity index will be calculated by subtracting the shut-in pressure from the measured injection pressures and dividing the difference into each flow rate.

$$\frac{\text{Flow (gpm)}}{[\text{pumping pressure (psig) - shut-in pressure (psig)}]} = \text{gpm/psig}$$

When the test is completed, the operator will return the pump controls to the AUTO position.

7.0 REFERENCES CITED

Applin, P. L., and Applin, E. R., 1944, Regional subsurface stratigraphy and structure of Florida and southern Georgia: Am. Assoc. Petroleum Geologists Bull, v. 28, p. 1673-1753.

Chen, C. S., 1965, The regional lithostratigraphic analysis of Paleocene and Eocene rocks of Florida: Florida Geological Survey Bulletin No. 45, 105 p.

Cole, W. S., 1944, Stratigraphic and paleontologic studies of wells in Florida: Fla. Geol. Survey Bull. 26, 168 p.

Deuerling, R. J., 1983, Class I injection well inventory: Florida Dept. of Environmental Regulation, 66 pp.

Haberfeld, J. L., 1991, Hydrogeology of effluent disposal zones, Floridan Aquifer, South Florida: Ground Water, Vol. 29, No. 2, p. 186-190.

Hickey, J. J., 1990, Use of borehole video surveys to describe secondary porosity of carbonate rocks of the Floridan Aquifer. Oral presentation. Underground Injection Control Workshop, Tallahassee, Florida.

Hunter, M. E., 1968, Molluscan guide fossils in late Miocene sediments of southern Florida: Gulf Coast Assoc. of Geological Societies Transactions, v. 18, p. 439-450.

Mansfield, W. C., 1939, Notes on the upper Tertiary and Pleistocene mollusks, peninsular Florida: Fla. Geol. Sur., Geological Bull. no. 18, 57 p.

Meeder, J. F., 1979, A field guide with road log to the Pliocene fossil reef of Southwest Florida: Miami Geological Society Field Trip, Jan. 20-21, 1979.

Missimer & Associates, Inc., 1981, Groundwater resources of the Bonita Bay Development, Lee County, Florida.

Missimer, T. M., 1984, The geology of South Florida: A summary in Environments of South Florida Present and Past II, P. J. Gleason, Editor: Miami Geological Society, memoir 2, p. 385-404.

Parker, G. G., and others, 1955, Water Resources of Southeastern Florida, with special reference to the geology and groundwater of the Miami area: U.S.G.S. Water Supply Paper 1255.

Puri, H. S. 1957, Stratigraphy and zonation of the Ocala Group: Fla. Geol. Survey Bull. 38, 248 p.

Puri, H. S., and Winston, G. O., 1974, Geologic framework of the high transmissivity zones in South Florida: Florida Bureau of Geology special Publication 20, 101 pp.

Scott, T. M., 1988, The Lithostratigraphy of the Hawthorn Group (Miocene) of Florida: Florida Geological Survey Bulletin No. 59, 148 p.

Singh, W. P., Eichler, G. E., Sproul, C. R., and Garcia-Bengochea, J. I., 1983, Pump testing Boulder Zone aquifer, South Florida: Journal of Hydraulic Engineering, v. 9, no. 8, p. 1152-1160.

Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986, Hydrogeology units of Florida: Florida Geological Survey, Special Publication No. 28, 9 p.

Vernon, R. O., 1951, Geology of Citrus and Levy counties: Fla. Geol. Survey Bull. 33, 256 pp.