UPPER FLORIDAN AQUIFER

AQUIFER PERFORMANCE TEST REPORT

FOR

INDIANTOWN COGENERATION PROJECT

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March 22, 1994

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VOLUME 1

INDIANTOWN COGENERATION PROJECT

Prepared for

U.S. GENERATING COMPANY

March 1994

Bechtel Power Corporation
Gaithersburg, Maryland

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List of Acronyms and Abbreviations

APT	Aquifer Performance Test
BOP	blow-out-preventor
COC	Conditions of Certification
El.	Elevation
FPL	Florida Power & Light Company
gpd/ft	gallons per day per foot (of drawdown)
gpm	gallons per minute
ICL	Indiantown Cogeneration Limited Partnership
mgd	million gallons per day
mg/l	milligrams per liter
mgy	million gallons per year
msl	mean sea level
NGVD	National Geodetic Vertical Datum
O.D.	outside diameter
psi	pounds per square inch
PVC	polyvinyl chloride
SCA	Site Certification Application
SFWMD	South Florida Water Management District
TDS	total dissolved solids

1.0 EXECUTIVE SUMMARY

Three wells were drilled into the Upper Floridan aquifer at the Indiantown Cogeneration Plant site. The borehole for well IPW-2 was drilled to a depth of 1,265 feet below the ground surface. The well was completed in the Upper Production Zone of the Upper Floridan aquifer with a finished casing diameter of 10-3/4 inches to a depth of 750.5 feet and an open hole diameter of 9-7/8 inches to the bottom of the well. The boreholes for wells ICW-1 and ICW-2 were drilled to depths of 1,640 and 1,660 feet, respectively. The wells were completed in the Lower Production Zone of the Upper Floridan aquifer with a finished casing diameter of 16 inches to depths of about 1,487 and 1,478 feet, respectively, and an open hole diameter of 15 inches to the bottom of the wells. For each well, casings of decreasing diameter were sequentially installed during drilling so that each aquifer and/or production zone was sealed off from the borehole before drilling into the next lower aquifer/zone.

Geophysical logging was performed in each of the wells. Parameters measured during the geophysical logging included resistivity, natural gamma, temperature, fluid conductivity, borehole diameter, borehole flow velocity, and cement bond.

The three wells, and a fourth well constructed previously at the site (IPW-1), were utilized in the performance of two aquifer performance tests (APTs) - one in the Upper Production Zone and one in the Lower Production Zone of the Upper Floridan aquifer - to determine aquifer hydraulic parameters. Well ICW-2, during an intermediate step in its construction and following its completion, was utilized as the pumping well for the two tests while the remaining wells were utilized as observation wells to determine ground water level responses to the pumping from ICW-2. The aquifer water produced by the APT pumping was discharged to the onsite APT basin at the southern end of the cooling water storage pond. Following completion of the APTs, the wells were completed for use as a source of backup process and cooling water supply by the Indiantown cogeneration plant during periods of extended drought conditions.

From the analysis of the APT data, the transmissivity and storage coefficient of the Upper Production Zone were determined to be 205,000 gpd/ft and 0.0003, respectively. The Lower Production Zone transmissivity was determined to be 2,300,000 gpd/ft and the storage coefficient was determined to be 0.00013. A leakage coefficient of 0.0032 day^{-1} was computed for the semi-confining zone separating the Upper and Lower Production Zones, based on the analysis of the Upper Production Zone test data.

Impacts to area ground water users were computed using a numerical flow model. The model, which incorporated the hydrogeologic parameters determined from the pumping tests, showed that withdrawing ground water at rates of 300 gpm (0.43 mgd) from the Upper Production Zone and 3,097 gpm (4.46 mgd) from the Lower Production Zone for a period of 75 days, in accordance with the maximum daily authorized withdrawal allocation contained in the Conditions of Certification (COC) for the Project, would not adversely impact any legal ground water user in the vicinity of the Indiantown Cogeneration Plant. The model also showed that none of these users would be adversely impacted if 300 gpm (38.70 mgy) was withdrawn from the Upper Production Zone and 2,597 gpm (336.60 mgy) was withdrawn from the Lower Production Zone for a period of 90 days, in accordance with the maximum annual authorized withdrawal allocation also contained in the COC.

2.0 INTRODUCTION

This report presents the results of activities performed to satisfy requirements of the South Florida Water Management District (SFWMD) contained in the COC, Part IV.B.3.a. (p. 38), included as part of the Final Order of Certification issued by the Governor and Cabinet of the State of Florida for construction of the Indiantown Cogeneration Project. The work was performed in accordance with the final APT Work Plan submitted and accepted by the SFWMD in their letter LAN 04-02, dated March 24, 1993 (SFWMD, 1993a). The work conducted included installation of three Upper Floridan aquifer wells, the performance of two APTs, analyses to determine water quality and aquifer parameters, and analyses to determine the impact of the proposed ground water withdrawals on surrounding users of the Upper Floridan aquifer. The information contained in this report is intended to be used by the SFWMD to confirm or modify their previously authorized ground water withdrawal allocations contained in the COC and to determine if there is any need for impact mitigation.

The Indiantown cogeneration plant proposes to obtain its process water and cooling water makeup supply from two separate production zones within the Upper Floridan aquifer during periods when the water level in the primary surface water source, the L-63N Canal, falls below an elevation of 17.50 feet NGVD (COC, Part IV.B.2.b.(2), p. 36). Withdrawals from the Upper Floridan aquifer are limited in the COC (Part IV.B.2.b.(6), p. 37) to a total of 90 days during any consecutive 365-day period without prior approval from the SFWMD. The maximum annual allocation for the 90-day withdrawal is 38.70 million gallons per year (mgy) from the Upper Production Zone of the Upper Floridan aquifer and 336.60 mgy from the Lower Production Zone of the Upper Floridan aquifer. In addition, a maximum daily withdrawal allocation of 0.43 million gallons per day (mgd) from the Upper Production Zone and 4.46 mgd from the Lower Production Zone is authorized for a period not to exceed 75 days (COC, Part IV.B.2.a., p. 36). These allocations correspond to maximum withdrawals of approximately 300 gallons per minute (gpm) from the Upper Production Zone and 3,100 gpm from the Lower Production Zone.

A previous report (Bechtel, 1991), which presents the results of a preliminary hydrogeologic field investigation and a computer analysis of the impacts of ground water withdrawal for the Indiantown Cogeneration Project, was prepared and submitted to the SFWMD as part of the Site Certification Application (SCA) process. The report also contains background information on the presence of two significantly different water-bearing layers (production zones) within the Upper Floridan aquifer, discusses the frequency at which plant ground water withdrawals will be required, and presents data on surrounding permitted users of the Floridan aquifer. The information presented in the previous report was based on the results of drilling test hole IPW-1 to a depth of 1,702 feet at the site and a computer analysis using published and unpublished hydrogeologic parameters for the Upper Floridan aquifer. Upon completion of drilling, the hole was completed as well IPW-1 by plugging the bottom 362 feet with cement grout, resulting in a finished well depth of 1,340 feet.

The purpose of the preliminary investigation was to provide information to the SFWMD for use in determining water allocations from the Upper Floridan aquifer as a backup water supply for the Indiantown plant. The results of this investigation provided evidence for the lithologic correlation of strata between Florida Power & Light Company's (FPL) Martin Plant site, about 3.8 miles to the northwest, and the Indiantown Cogeneration Project site. The results also supported the presence of Upper and Lower Production Zones, separated by a semi-confining zone, within the Upper Floridan aquifer beneath the Indiantown site. Impacts on area ground water users that would be caused by the temporary withdrawal of ground water from these production zones were computed based on hydrogeologic parameters within the ranges of values observed elsewhere in the area. Only two existing permitted wells in the vicinity of the Indiantown site were determined to be susceptible to adverse impacts caused by ground water withdrawal from the aquifer by the plant. Both of these wells are owned by VIA Tropical Fruits, Inc. (Caulkins Indiantown Citrus Company), with whom a mitigation agreement was previously reached should any impacts occur. In addition, an evaluation of the potential for degradation of ground water in the Upper Production Zone as the result of upconing of saline water from the Lower Production Zone indicated that such an occurrence is unlikely due to the thickness of the intervening semi-confining zone and the maximum 90-day duration of withdrawal per year by the plant.

The results of the latest investigation, presented in the following sections, are intended to refine the results of the previous study by providing site specific aquifer parameters and then using these parameters in the ground water withdrawal impact analysis. The information obtained from this investigation was used to estimate the average production capacity of the ground water supply wells, the final number of wells required, and the impact of the Indiantown plant's ground water withdrawal on surrounding users of the Floridan aquifer.

3.0 WELL CONSTRUCTION AND TESTING

3.1 Scope of Work

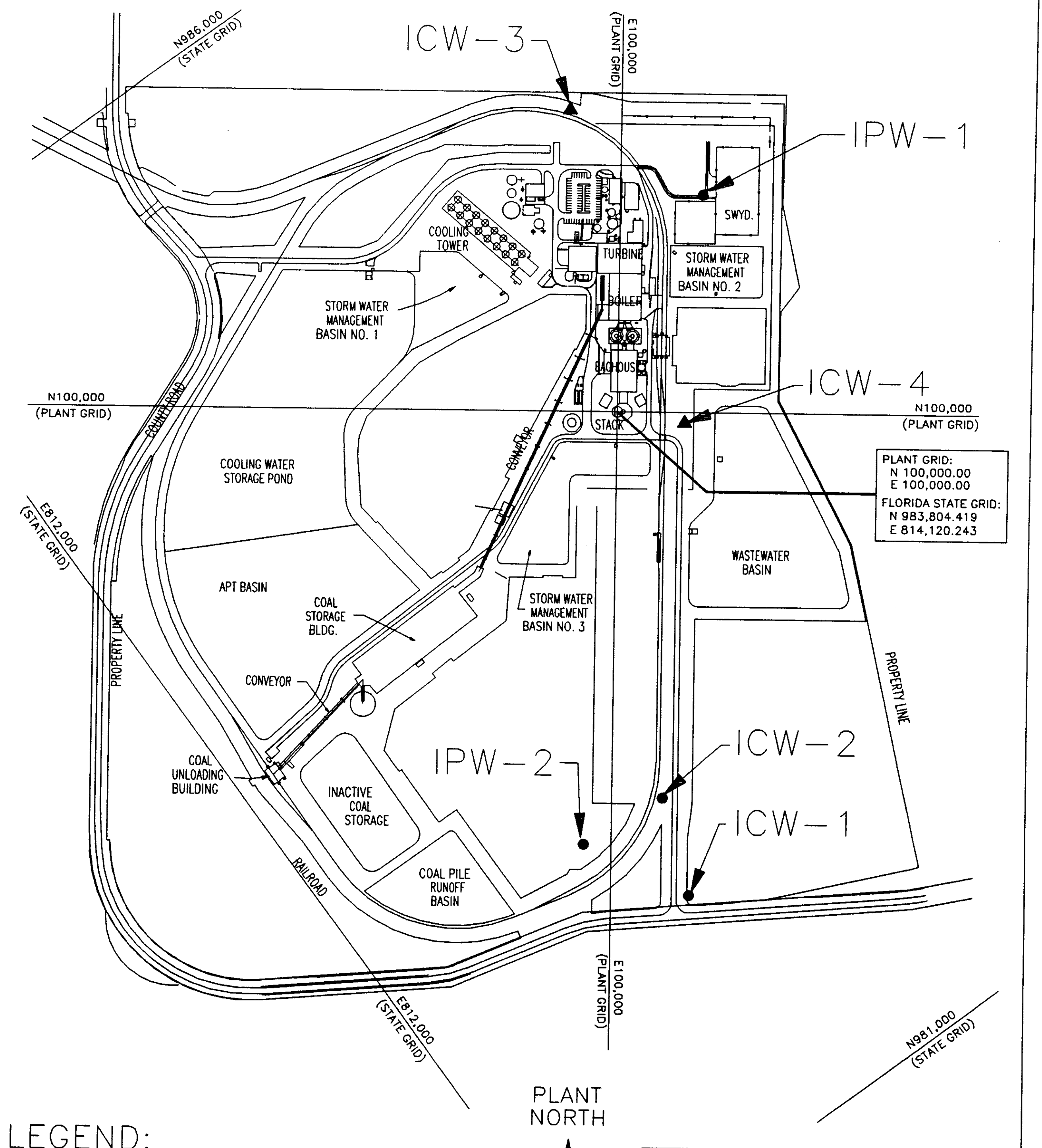
Three wells were constructed at the Indiantown site in the latter half of 1993 to obtain site-specific information on the physical and hydrogeologic characteristics of the Upper and Lower Production Zones of the Upper Floridan aquifer. A fourth well, drilled at the site in mid-1991 and designated IPW-1 (Bechtel, 1991), was also utilized during the investigation. Data obtained from the latest drilling and testing activities include thickness, lithology, transmissivity, and storage coefficients of the two aquifer zones and the leakage coefficient between them. This information was developed from logs of the wells and from the results of two APTs. All of these wells will be integrated into the plant backup water supply system.

3.2 Work Performed

3.2.1 General

The three Indiantown wells constructed for this investigation were designated IPW-2, ICW-1 and ICW-2 and are located at the south-central end of the property (Figure 1), in Section 34 of T39S, R38E. Well IPW-1 (Bechtel, 1991) is located in the northeast corner of the property (Figure 1), in Section 35 of T39S, R38E.

SFWMD approval of the latest well construction was considered to have been granted under the COC. Therefore, standard well construction permits were not required (SFWMD, 1993b). However, permit applications for the wells were submitted to the SFWMD for information purposes. Drilling, well construction and aquifer performance testing were performed by Diversified Drilling Corporation of Tampa, Florida, under the direction of a Bechtel hydrogeologist. Grouting and casing welding services were provided by Southern Well Services of Odessa, Florida. Additional grouting services were provided by Halliburton



LEGEND:

IPW-2 ● Existing Floridan Aquifer Well

ICW-3 ▲ Proposed Floridan Aquifer Well

0 600 FT

SCALE

BECHTEL POWER CORPORATION GAITHERSBURG, MARYLAND		
INDIANTOWN COGENERATION PROJECT INDIANTOWN, FLORIDA		
FLORIDAN AQUIFER WELL LOCATIONS		
JOB NO.	FIGURE NO.	REV.
22019-001	FIGURE 1	0

GEOTECHNICAL & HYDRAULIC ENGINEERING SERVICES DESIGNCAD 2D DRAWING L:\INDTOWN\DC\FIGURE1.DW2 3/14/94

Energy Services of Felda, Florida. Geophysical logging was performed by Southern Resource Exploration of Gainesville, Florida. Laboratory water quality analysis was performed by Paul R. McGinnes and Associates Consulting Laboratories, Inc. of West Palm Beach, Florida.

Drilling for well construction was initiated on August 4, 1993. All field work associated with well construction and aquifer performance testing was completed by December 23, 1993.

3.2.2 IPW-2 Construction

The construction of well IPW-2 (Figure 1) was initiated on August 9, 1993 and the well was completed with installation of the permanent Tee and gate valve with monitoring ports for measurement of aquifer pressure head and monitoring ports on October 7, 1993. The well is designed to be open to the Upper Production Zone of the Upper Floridan aquifer with appropriate sealing through the Surficial aquifer and the intervening confining layers (Hawthorn Group). In addition, the depth of the well was controlled to be open to most of the producing zone without penetration of the confining layer below, thus minimizing the possibilities for degradation of the water quality with time from upward migration of poorer quality water from the Lower Production Zone.

The well was drilled for the following purposes:

1) as a monitoring well, open to the Upper Production Zone, during the APT in the Upper Zone and the Lower Zone; and

2) as a backup process water supply well.

The hole for well IPW-2 was drilled utilizing conventional mud rotary techniques through the upper 831 feet. From 831 feet to the final depth of 1,265 feet, reverse air rotary techniques were used.

The drilling and well construction was performed as described below:

- A 12-1/4-inch diameter pilot hole was drilled to a depth of 185 feet to determine the cased depth for the surface casing.

- The hole was enlarged to a minimum diameter of 22 inches to a depth of 187 feet. A viscosifier was added to the drilling fluid as necessary to assist in removal of the heavier cuttings and to reduce the wall cake build-up.

- Surface casing with an outside diameter (O.D.) of 16 inches was installed in the reamed hole to a depth of 186.3 feet below the ground surface and grouted in place with bentonite/cement grout pumped through 2-inch diameter steel and polyvinyl chloride (PVC) pipe placed inside the sealed casing. The total grout pumped to fill the annulus was 11.8 cubic yards.

- The 12-1/4-inch diameter pilot hole was drilled beyond the base of the Hawthorn Group sediments, to a depth of 756 feet below the ground surface, to determine the final depth for placement of the well casing.

- The pilot hole was enlarged to a minimum of 15 inches in diameter to a depth of 754 feet. A caliper log was run to verify the minimum hole diameter and 10-3/4-inch O.D. steel casing was installed to a depth of 750.5 feet and grouted in-place with bentonite/cement grout. Grout was pumped through 2-inch diameter steel and PVC pipe placed to a depth of 720 feet in the casing. The well casing was sealed and a total of 21.2 cubic yards of grout was pumped from the bottom of the casing until returns were observed at the surface. The grout was allowed to set for about 4 days before drilling resumed.

- A temperature log was run in the well casing about 16 hours after grout placement. Logging of the interval was performed from the top of the casing to a depth of 728 feet. The logging instrument stopped in heavy grout latents and drilling fluid at that depth.

- Additional grout, 0.8 cubic yards to make up for settlement and shrinkage in the annulus, was placed by the tremie method above a depth of 32.75 feet. A casing integrity test was then performed about 50 hours following the initial grout placement. The casing was pressurized to 120 pounds per square inch (psi) and the well head sealed. The pressure was observed to be 9 psi lower after a period of one hour.

- The top of the nominal 10-inch diameter casing was trimmed to within 4 inches of the ground surface and a 10-inch diameter flange and a temporary 10-inch diameter Tee bolted onto the top of the casing. A blow-out-preventor (BOP) was fabricated and attached to the temporary Tee to control artesian water flow during periods when no work was being performed on the well. Grout which had set up in the casing from a depth of 739 to 754 feet was reamed out using a 9-7/8-inch diameter bit. Hole advancement continued using conventional rotary drilling. At a depth of 831 feet, the hole was circulated clean of drill cuttings and the drilling fluid removed to allow drilling to continue using the reverse air rotary drilling method.

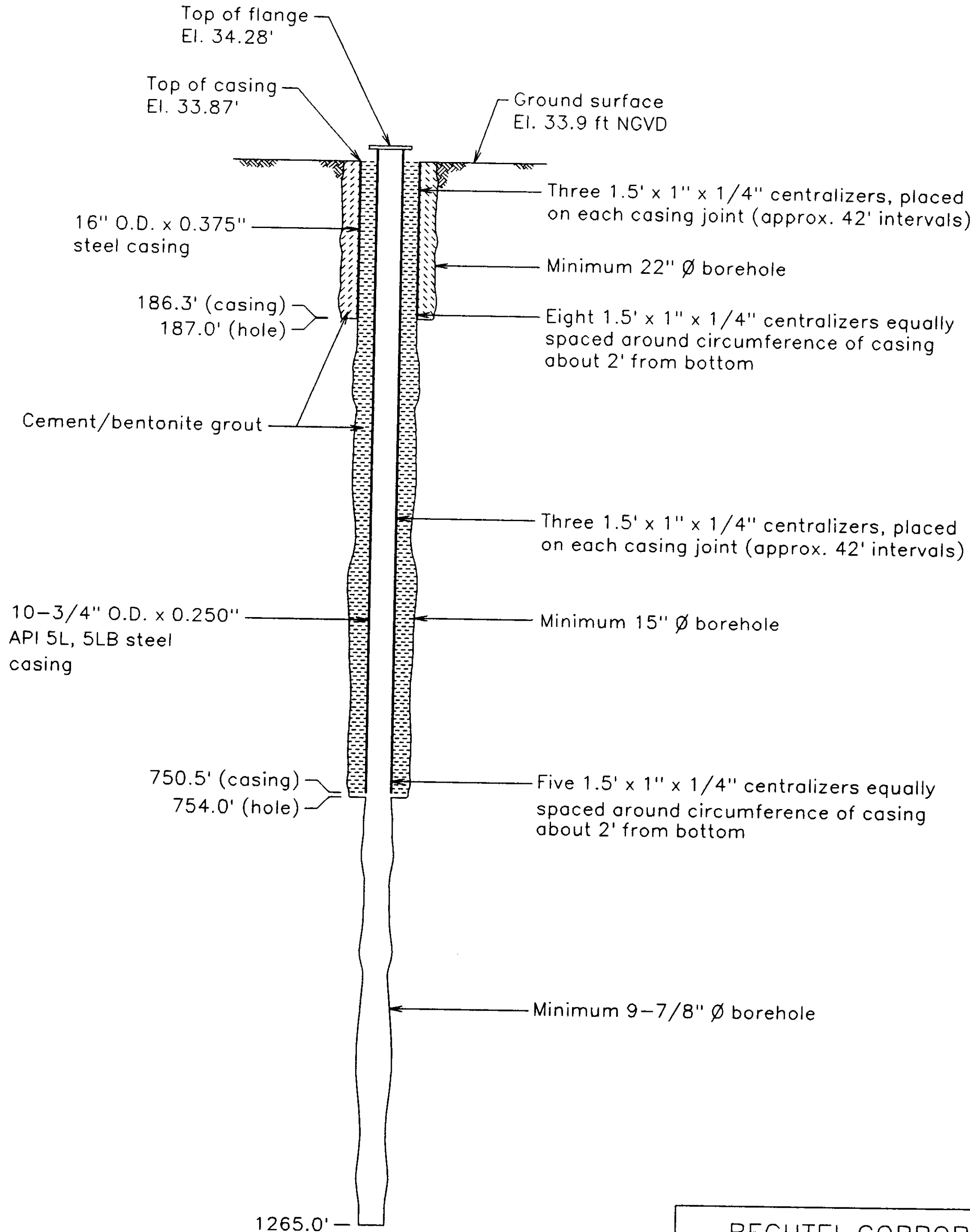
- The 9-7/8-inch diameter hole was drilled from a depth of 831 feet to the bottom of the hole at a depth of 1,265 feet using the reverse air rotary technique. Artesian well flow occurred at a depth of 830 feet. During drilling, the air-lifted discharge was directed to a natural drainage channel which, in turn, discharged to the existing drainage ditch running through the Indiantown site. Besides separation of the coarse drill cuttings by discharge of the air-lifted cuttings over a shaker screen, settlement of the fine-grained drill cuttings was provided by passing the discharged water through a temporary pit excavated in the drainage swale.

- The well was developed for 6 hours using air lifting to stimulate flow. There was an absence of sediment and a minimum of clouding during air lifting. Open flow discharge following air-lift development was about 440 to 455 gpm.

- The temporary Tee and discharge assembly was removed from the wellhead and replaced by a permanent 10-inch diameter Tee, gate valve, blind flanges, and access points to allow monitoring of the piezometric head and water sampling.

- Geophysical logging, consisting of gamma, resistivity, spontaneous potential, caliper, temperature, flowmeter, fluid resistivity, acoustic and cement bond logs, was performed in the well from 0 to 1,265 feet and 740 to 1,265 feet, as appropriate.

A diagram of the completed well is shown on Figure 2. Since completion, the well has been used as a monitoring well during the two APTs and for flow testing to determine the well capacity. The concrete slab around the well casing will be constructed when the other surface facilities at the well site are completed.



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INDIANTOWN, FLORIDA

COMPLETION DIAGRAM
WELL IPW–2

JOB NO.	FIGURE NO.	REV.
22019–001	FIGURE 2	0

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3.2.3 ICW-1 Construction

The construction of well ICW-1 (Figure 1) was initiated on August 4, 1993, and the well was completed with installation of the permanent Tee, valve and monitoring points on the well casing on October 18, 1993. This well was drilled and installed first to provide design guidelines for the construction of well ICW-2 with respect to casing depths and aquifer sealing methodology, and to verify the depths of the Upper and Lower Production Zones within the Upper Floridan aquifer and the thickness of the confining zone separating them. Well ICW-1 was designed and constructed to be open to the Lower Production Zone only. Sealing through the overlying strata was performed using grouted-in-place casing.

Following its completion, ICW-1 was used as a monitoring well open to the Lower Production Zone during the APT in the Lower Zone. It is also intended to be used as a source for the plant backup cooling water supply.

The hole for the well was drilled using conventional mud rotary techniques through its upper 836 feet and reverse air rotary drilling from there to the final hole depth of 1,640 feet.

The drilling and well construction was performed as described below:

- A 12-1/4-inch diameter pilot hole was drilled to a depth of 185 feet to determine the cased depth for the surface casing.

- The hole was enlarged to 34-3/4-inch diameter to a depth of 188 feet. A viscosifier was added to the drilling fluid as necessary to assist in removal of the heavier cuttings and to reduce wall cake build-up.

- Steel surface casing, 28 inches in diameter, was installed in the reamed hole to a depth of 185.6 feet below the ground surface and grouted in-place with bentonite/cement grout pumped through 2-inch diameter steel and PVC pipe placed inside the sealed casing. The total grout pumped into the annulus was 21.7 cubic yards. An additional 8.2 cubic yards was pumped into the annulus by the tremie method to raise the grout level to the ground surface.

- The 12-1/4-inch diameter pilot hole was advanced beyond the base of the Hawthorn Group sediments, to a depth of 750 feet below the ground surface, to determine the final depth for placement of the well casing.

- The pilot hole was enlarged to a minimum 27 inches in diameter to a depth of 733 feet. Drill fluid control was maintained by pumping off the heavier fluids and using Thinz-It. A caliper log was run to verify the minimum hole diameter.

- Spiral-weld steel casing, 22 inches in diameter, was installed in a continuous operation to a depth of 729.5 feet and grouted in-place with bentonite/cement grout. The grout was pumped through 2-inch diameter steel and PVC pipe placed to a depth of 712 feet. The casing was sealed and a total of 34.6 cubic yards of bentonite/cement grout was pumped from the bottom of the casing. A temperature log was run through the cased interval to a depth of 718 feet about 12 hours after grouting. The grout in the annulus was measured at a depth of 368 feet below the ground surface and an additional 23.4 cubic yards of grout was pumped into the annulus, raising the grout level to within 12.5 feet of the ground surface. A second temperature log was run through the cased interval about 13 hours after the completion of grouting. An additional 0.9 cubic yards of neat cement was added to raise the grout level to the ground surface.

- The top of the 22-inch diameter casing was cut to within one foot of the ground surface and a 22-inch diameter flange and 22x10-inch Tee was fabricated and attached to the 22-inch diameter casing. A BOP was fabricated and attached to the 22-inch diameter Tee to secure the well during those periods when no work was being performed on the well. Grout in the casing was reamed out from a depth of 722 to 729.5 feet.

- The hole was advanced below the 22-inch diameter casing with the 12-1/4-inch diameter pilot bit to a depth of 836 feet. The drill fluid was then circulated out of the hole and replaced with water prior to drilling below this depth using the reverse air rotary drilling method.

- Pilot hole drilling continued using reverse air to a depth of 1,525 feet. Due to the weight of the drilled slurry (water and fine formation cuttings) in the hole, fluid levels in the well remained below the top of the casing until the boring reached a depth of 1,330 feet. At this depth, artesian water flow at the surface was 5 to 10 gpm. At a depth of 1,525 feet, the well was allowed to develop naturally overnight. In the morning, the well water flow was estimated at 800 to 900 gpm. During further well development, the flow rate increased to over 1,100 gpm and exhibited changes in chloride concentration and conductivity below a depth of 1,500 feet. Flow from the well was directed westerly across the south site access road to a surface drainage (swale) on the north side of the recently completed perimeter road (future county road) around the project site. Flow from the swale enters the existing drainage ditch.

- A suite of geophysical logs was run through the cased and open hole intervals as appropriate for the various logs. Based on these logs, flow rates, and water quality changes, a depth of 1,490 feet was selected for the bottom of the well casing.

- The pilot hole was reamed to a minimum diameter of 21 inches to a depth of 1,495 feet. Caliper and flowmeter logs were run on the reamed hole to verify the minimum hole diameter and assist in the verification of well sealing following casing installation.

- Following reaming, well flow was controlled by the injection of a salt slurry into the 22-inch diameter casing. The water level in the casing was further depressed by the addition of bulk salt.

- The 16-inch O.D. well casing was installed over a period of 3 days to 1,487.1 feet below the ground surface. Centralizers were attached over each casing joint in the lower 590 feet of the well and over alternate casing joints occurring throughout the remainder of the open hole and within the 22-inch diameter casing. Tremie pipe, 2-inch diameter steel and PVC, was set to a depth of 1,440 feet and an initial 34.6 cubic yards of bentonite/cement grout was pumped through the well casing into the annulus. A temperature log was run to a depth of 1,446 feet about 10 hours after the completion of grouting. The top of the grout was measured, using a 1-1/2-inch diameter tremie pipe, at a depth of 1,230 feet in the annulus outside the 16-inch diameter casing. An additional 86.4 cubic yards of grout was pumped into the annulus in six stages. A minimum of 8 hours curing time was allowed between stages. A second temperature log was run to a depth of 906 feet about 10 hours after pumping the last grout stage to confirm the continuity of grout placement between the 16-inch and 22-inch diameter casings.

- A casing integrity test was attempted after allowing the grout seal time to cure. However, the casing could not be made to hold pressure due to leaks in the pipe fittings between the pump and the well head.

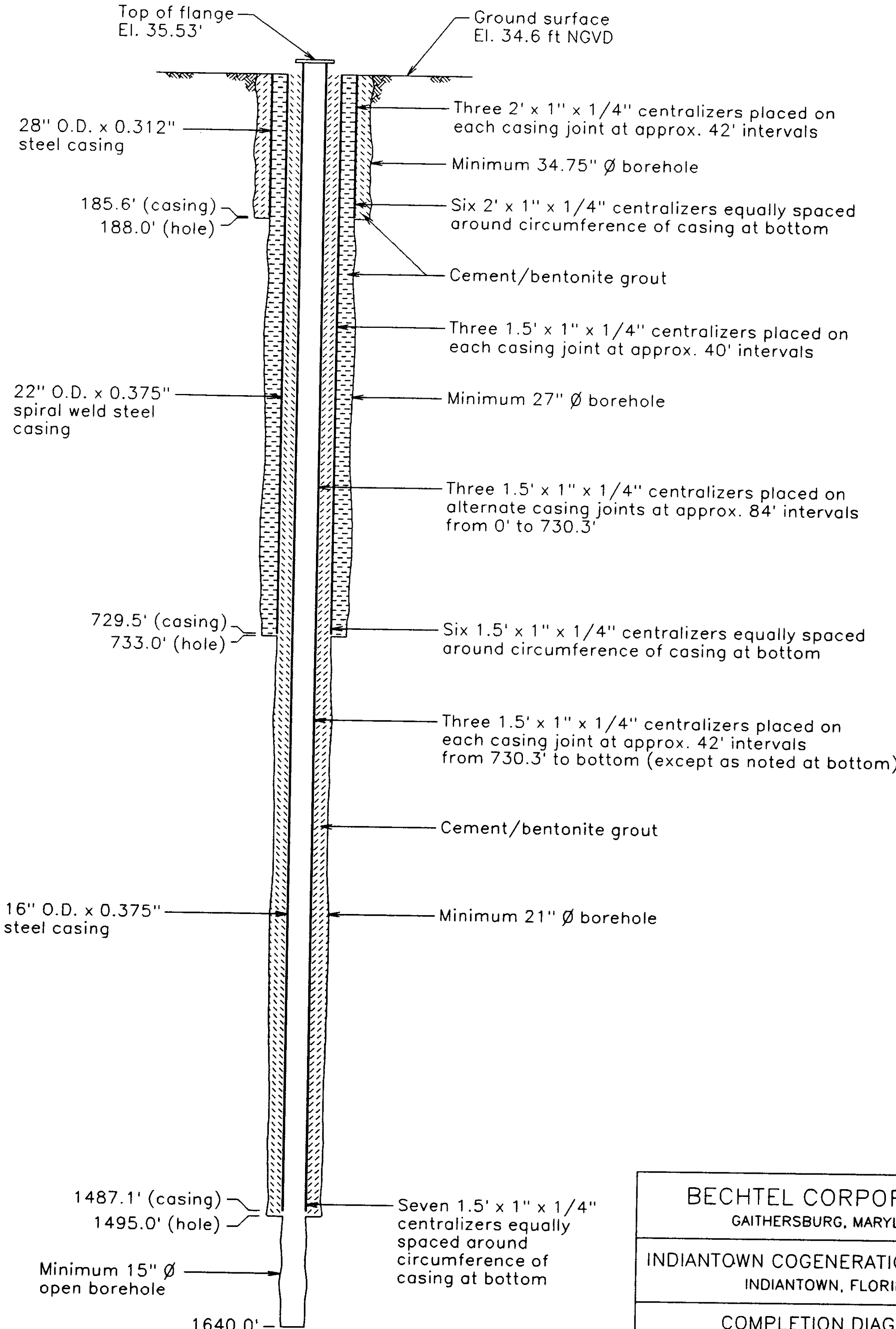
- Upon re-entry into the casing with a 15-1/4-inch diameter tricone bit, grout was encountered at a depth of 1,474 feet. The salt added to control well flow was diluted with 15,000 gallons of water and flushed out of the well casing. The water flushed from the casing was further diluted with fresh water prior to its discharge.

- The open hole portion of the well in the Lower Production Zone was advanced with the 15-1/4-inch diameter bit to a total depth of 1,640 feet. The well was terminated at this depth due to an increase in chlorides and conductivity. The estimated well water flow upon completion was 1,100 to 1,200 gpm.

- The well was developed with air for a period of one hour and allowed to flow while the drilling tools were removed.

- The temporary 16x10-inch Tee and BOP were removed and replaced with the permanent 16-inch diameter Tee and gate valve assembly, blind flanges, and monitoring points to allow piezometric head measurements and water quality sampling. A suite of geophysical logs was run in the open hole portion of the well and a cement bond log was run in the cased portion of the hole.

A diagram of the completed well is shown on Figure 3. The concrete slab around the well casing will be constructed when the other surface facilities at the well site are completed. The well was used for monitoring water levels during the APTs and will be used as a source for the plant backup cooling water supply.



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INDIANTOWN COGENERATION PROJECT INDIANTOWN, FLORIDA		
COMPLETION DIAGRAM WELL ICW-1		
JOB NO.	FIGURE NO.	REV.
22019-001	FIGURE 3	0

3.2.4 ICW-2 Construction

The construction of well ICW-2 (Figure 1) was initiated on September 14, 1993, and was competed on December 22, 1993. The well was designed to be used as the pumping well for the APTs conducted in both the Upper and Lower Production Zones of the Upper Floridan aquifer. Well construction was, therefore, performed in two steps so that it could be used for both APTs. Initially, the well was constructed as a cased well open to the Upper Production Zone. Following the APT in the Upper Zone, the uncased portion of the hole in the Upper Zone was enlarged and the hole deepened to accommodate casing installation and sealing of the Upper Production Zone prior to advancement of the hole into the Lower Production Zone. The hole was then advanced to a final depth of 1,660 feet in the Lower Zone where the second APT was performed.

Well ICW-2 was designed and constructed to be open to the Lower Production Zone only. Sealing through the overlying strata was performed using grouted-in-place casing. The well is intended to be used as a source for the plant backup cooling water supply.

The drilling and construction was performed as described below:

- A 12-1/4-inch diameter pilot hole was drilled to a depth of 214.7 feet to determine the cased depth for the surface casing.

- The hole was enlarged to a diameter of 34-3/4 inches to a depth of 190.4 feet. A viscosifier was added to the drilling fluid as necessary to assist in removal of the heavier cuttings and to reduce wall cake build-up.

- Steel surface casing, 28 inches in diameter, was installed in the reamed hole to a depth of 188.4 feet below the ground surface and grouted in-place with bentonite/cement grout pumped through 2-inch diameter steel and PVC pipe placed inside the sealed casing. The total grout pumped to fill the annulus was 21.5 cubic yards. An additional 0.75 cubic yards was pumped into the annulus by the tremie method to raise the grout level from a depth of 20 feet to the ground surface.

- The 12-1/4-inch diameter pilot hole was advanced through the Hawthorn Group sediments to a depth of 750 feet to determine the final depth for placement of the well casing.

- The pilot hole was enlarged to a minimum diameter of 27 inches to a depth of 755 feet. Drill fluid control was maintained by pumping off the heavier fluids and using Thinz-It. In addition, a second mud pump was used in series to increase the quantity of fluid flow through the lower portions of the drilling to lift the heavier drill cuttings. Upon completion, a caliper log was run to verify the minimum hole diameter.

- Spiral-weld steel casing, 22 inches in diameter, was installed, in two shifts, to a depth of 738.7 feet and grouted-in-place with bentonite/cement grout. The grout was pumped through 2-inch diameter steel and PVC pipe placed to a depth of 710 feet. The casing was sealed and a total of 34.6 cubic yards of bentonite/cement grout was pumped from the bottom of the casing. A temperature log was run through the cased interval to a depth of 721 feet about 13 hours after the completion of grouting. The log indicated a lack of uniform grout placement in the annulus throughout the cased interval. The annulus was probed and grout encountered at depths of from 20 feet to 177 feet below the top of the 28-inch diameter casing. Water was injected into the 22-inch diameter casing at pressures ranging from 70 to 250 psi resulting in takes ranging from 6.5 to 15.5 gallons. The reaming bit was placed in the casing and drilling fluid and grout were displaced by water, in stages, to a depth of 742 feet. The lower 50 feet of the casing was filled with 6.2 cubic yards of grout. The 22-inch diameter casing was pressurized at the surface and 0.7 cubic yards of grout were displaced from the bottom of the casing into the annulus over a period of 1.5 hours. The fluid in the upper 177 feet of the annulus was circulated to flush out drilling fluid and cuttings and 2.9 cubic yards of grout were pumped in to seal the casing to the ground surface. After curing for 21 hours, the grout was drilled out of the cased and uncased portion of the hole from a depth of 696 to 745 feet.

- The drill rig which had been used to construct the well to its current depth was then demobilized and replaced by the drill rig used to construct well ICW-1 due to its greater load capacity for installation of the subsequent casing string.

- The top of the 22-inch diameter casing was cut to 0.64 feet above the ground surface followed by the welding on of a temporary flange. The 22x10-inch Tee section and BOP used on ICW-1 were then attached. Drilling fluid in the well casing was displaced by about 15,000 gallons of water as the pilot hole was advanced to a depth of 760 feet. Initial artesian water flow, at a rate of about 400 gpm, occurred at a depth of 765 feet.

- During reverse air drilling of the hole, flow was discharged via pipes to a graded ditch on the south side of the plant railroad embankment and flowed to the existing drainage ditch which runs through the Indiantown site property.

- The 12-1/4-inch diameter pilot hole was advanced to a depth of about 1,263 feet for performance of the Upper Production Zone APT. A suite of geophysical logs, including gamma, resistivity, spontaneous potential, caliper, temperature, flowmeter, fluid resistivity, and acoustic, were run through the completed portion of the well prior to setting up for the test.

- A vertical turbine pump was installed to a depth of 50 feet and a constant rate APT performed for a period of 29 hours at a rate of about 1,200 gpm. The well discharge was pumped through the permanent plant cooling water piping to the APT basin at the southern end of the plant cooling water storage pond, about 1,800 feet west of the well (Figure 1).

- Upon completion of the Upper Production Zone APT, the pump was removed and drilling of the 12-1/4-inch diameter pilot hole was continued to a depth of 1,500 feet. A suite of geophysical logs, including gamma, resistivity, spontaneous potential, caliper, temperature, flowmeter, fluid resistivity, and acoustic, were run in the interval from 1,263 feet to 1,500 feet. The pilot hole was enlarged to a minimum diameter of 21 inches to a depth of about 1,483 feet below the ground surface. Flowmeter and caliper logs were run in the reamed hole to verify the minimum hole diameter and assist in the verification of well sealing following installation of the 16-inch diameter casing. The initial flowmeter log was inconclusive with respect to the contribution of the Lower Production Zone to total flow and was, therefore, rerun after the flow was controlled by injection of a salt slurry and the water level depressed by the bulk addition of salt into the casing.

- Over a period of 3 days, 16-inch O.D. steel well casing was set to a depth of about 1,478 feet below the ground surface. Centralizers were placed on each joint through most of the previously uncased portion of the hole and on alternate casing joints within the 22-inch diameter casing. Tremie pipe, 2-inch diameter steel and PVC, was set to a depth of 1,431 feet and an initial 29.2 cubic yards of bentonite/cement grout was pumped through the sealed well casing into the annulus. A temperature log was run to a depth of 1,427 feet about 10.5 hours after the completion of grouting. The top of the grout was measured, using a 1-1/2-inch diameter tremie pipe, at a depth of 1,208 feet in the annulus outside the 16-inch diameter casing. An additional 77.6 cubic yards of grout was pumped into the annulus in six stages. A minimum cure time of 8 hours was allowed between stages. A second temperature log was run to a depth of 1,426 feet, about 11 hours after pumping the last grout stage, primarily to confirm the continuity of grout placement between the 16- and 22-inch diameter casings.

- A casing integrity test was performed prior to removal of the casing seal. The casing was pressurized to 151 psi and the well head sealed to monitor any pressure change. The pressure was about 7 psi lower after one hour.

- Upon re-entry into the hole with a 15-1/4-inch diameter tricone bit, grout was encountered at a depth of 1,427 feet. The salt added to control well flow was diluted with 15,000 gallons of water and flushed out of the well casing. The water flushed from the casing was further diluted with fresh water prior to its discharge.

- The open hole portion of the well in the Lower Production Zone was advanced with the 15-1/4-inch diameter bit to a total depth of 1,660 feet. The well was terminated at this depth due to a lack of increase in

A diagram of the completed well is shown on Figure 4. The concrete slab around the well casing will be constructed when the other surface facilities at the well site are completed.

3.2.5 Sampling

Field sampling, consisting of obtaining drill cuttings for lithologic log preparation and water sampling for field and laboratory water quality analysis, was performed during drilling for and construction of the three wells.

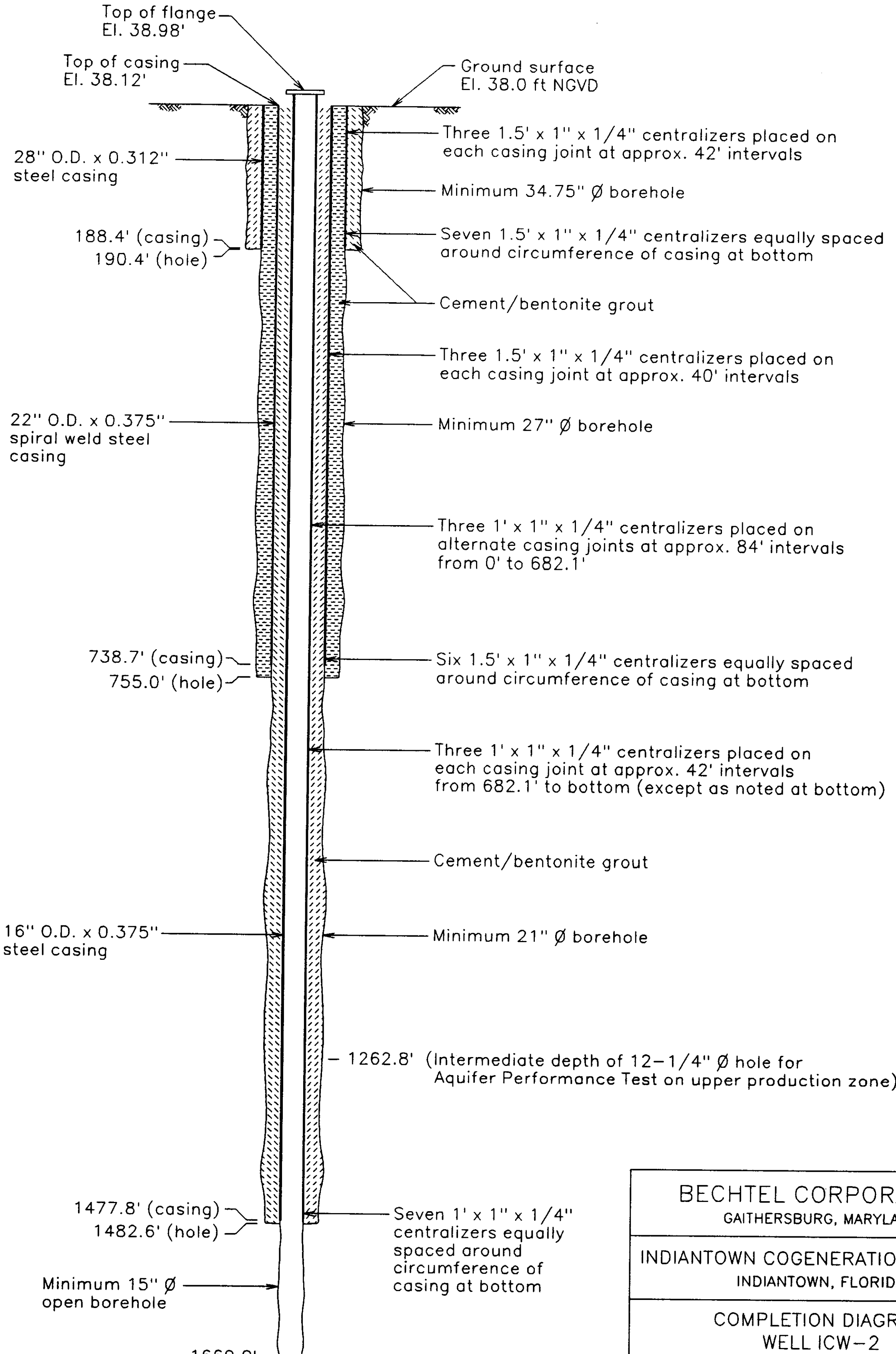
Drill Cuttings

Samples of subsurface materials encountered during drilling were obtained at 10-foot intervals as the drilling progressed. During mud rotary drilling, the samples were obtained from the shaker screen on the drill-fluid handling unit as the drill fluid, which was lifted by a pump from the drilling-fluid handling ditch, passed over the vibrating screen. During drilling using the reverse air rotary method, cuttings samples were also obtained from the shaker screen as the returns from the drill rod discharge passed over the vibrating screen.

The samples collected during drilling are stored in plastic bags at the Indiantown site for future reference. The samples obtained were visually identified, and a lithologic log prepared based on the visual descriptions. The lithologic logs of IPW-2, ICW-1 and ICW-2 are presented in Appendix A.

Water Quality Sampling

Sampling of the well discharge for water quality parameters was initiated when the reverse air rotary method was being used for hole advancement and sufficient formation water was entering the drill hole to sustain drilling without the addition of water. Water samples were obtained from the drill rod discharge following the completion of each drill stem advancement (29- to 32-foot intervals). The air-lifted discharge was allowed to clear of



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INDIANTOWN COGENERATION PROJECT
INDIANTOWN, FLORIDA

COMPLETION DIAGRAM
WELL ICW-2

JOB NO.	FIGURE NO.	REV.
22019-001	FIGURE 4	0

Geotechnical & Hydraulic Engineering Services Drawing L:\INDTOWN\DC\WELLS\ICW2.DW2 cuttings until relatively sediment-free water was being produced (usually 10 to 45 minutes) before collecting the sample. Analyses performed in the field included temperature, pH, conductivity and chloride. The results of these analyses are presented in Tables 1, 2 and 3.

During well construction, each well was also allowed to flow to open discharge. As the drilling progressed, water samples representing the total flow from water bearing zones below the lowest cased depth in the well were obtained from the casing discharge. The samples were analyzed in the field for the parameters indicated previously. Summaries of these analyses are presented in Tables 4, 5 and 6.

The field analyses were performed using a Hydac conductivity, temperature, pH tester manufactured by Cambridge Scientific Industries and a Hach Digital Titrator with reagents for chloride analysis. After completion of each analysis, the sample cup from the Hydac meter and the Hach glassware were rinsed with distilled and deionized water and allowed to air dry prior to the next analysis.

During the APTs, water samples were collected from ICW-2 for laboratory testing to determine total dissolved solids (TDS) content in addition to the same parameters for which field analyses were performed. The results of the laboratory analyses are summarized in Tables 7 and 8 and the laboratory test data sheets are contained in Appendix B. Additional discussion of the chemical water quality analyses is presented in Section 4.2.

3.2.6 Geophysical Logging

Geophysical logging was performed at various stages of drilling and well construction to provide data on hole size prior to casing installation, verify grout placement, identify producing zones within the Upper Floridan aquifer, and provide correlation of materials from well to well. The logging consisted of caliper, gamma ray, long and short normal electric, acoustic, temperature, fluid resistivity, flowmeter, and cement bond. The geophysical logs

Table 1

SUMMARY OF FIELD WATER QUALITY TEST RESULTS
DRILL STEM DISCHARGE FROM WELL IPW-2

Depth (ft)	Date	Temperature (°F)	pH	Conductivity (μmhos/cm)	Chloride (mg/l)
800	9/2/93	85.5	6.84	2,980	730
862	9/7/93	89.6	6.91	2,960	770
893	9/7/93	90.6	6.69	2,970	794
923	9/7/93	88.1	6.47	3,030	776
955	9/7/93	88.3	6.51	3,050	790
986	9/7/93	87.8	6.44	3,050	812
1,016	9/7/93	85.4	6.53	3,160	828
1,047	9/7/93	83.9	6.57	3,160	824
1,079	9/7/93	83.5	6.56	3,160	838
1,110	9/7/93	83.4	6.65	3,440	836
1,141	9/8/93	86.1	6.58	2,900	808
1,172	9/8/93	86.7	6.50	2,930	834
1,203	9/8/93	86.5	6.42	2,930	810
1,235	9/8/93	87.3	6.38	2,930	820
1,265	9/9/93	83.5	6.43	3,220	854

Table 2

SUMMARY OF FIELD WATER QUALITY TEST RESULTS
DRILL STEM DISCHARGE FROM WELL ICW-1

Depth (ft)	Date	Temperature (°F)	pH	Conductivity (μmhos/cm)	Chloride (mg/l)
836	9/8/93	87.9	6.59	3,000	794
866	9/8/93	88.5	6.53	2,930	826
897	9/8/93	87.5	6.33	2,960	838
928	9/8/93	88.2	6.45	2,950	830
990	9/8/93	85.8	6.76	3,060	844
1,018	9/9/93	86.8	6.39	3,050	814
1,052	9/9/93	86.3	6.76	3,030	840
1,083	9/10/93	81.3	6.47	3,110	838
1,114	9/10/93	86.2	6.27	2,940	820
1,146	9/10/93	88.8	6.18	2,870	846
1,177	9/10/93	89.5	6.12	2,900	812
1,208	9/13/93	87.8	5.95	2,940	838
1,238	9/13/93	88.8	6.09	2,970	810
1,268	9/13/93	88.6	6.21	3,040	840
1,299	9/13/93	86.6	6.78	3,050	836
1,330	9/13/93	85.6	6.43	2,850	850
1,361	9/14/93	82.6	6.50	3,180	890
1,392	9/14/93	84.5	6.31	3,180	836
1,422	9/14/93	84.2	6.43	3,110	820
1,453	9/14/93	81.8	6.27	3,250	840
1,485	9/14/93	82.3	6.57	3,250	800
1,514[a]	9/14/93	83.3	6.32	3,160	825
1,514[b]	10/12/93	86.7	8.25	7,280	2,780

Table 2 (Continued)

Depth (ft)	Date	Temperature (°F)	pH	Conductivity (μmhos/cm)	Chloride (mg/l)
1,525[a]	9/15/93	87.3	6.27	7,010	2,075
1,531	10/13/93	86.5	6.27	7,100	2,690
1,545	10/13/93	89.4	6.12	6,970	2,620
1,577	10/13/93	89.4	6.06	7,680	2,870
1,608	10/13/93	88.0	6.05	8,130	3,220
1,640	10/14/93	89.5	5.78	13,700	5,260

Notes: a) Sample obtained from pilot hole discharge prior to reaming and casing installation.
b) Sample obtained prior to hole advancement following installation of 16-inch diameter casing. pH reading is considered to be anomalous.

Table 3

SUMMARY OF FIELD WATER QUALITY TEST RESULTS DRILL STEM DISCHARGE FROM WELL ICW-2

Depth (ft)	Date	Temperature (°F)	pH	Conductivity (μmhos/cm)	Chloride (mg/l)
770	10/20/93	84.1	6.71	3,260	876
800	10/20/93	86.4	6.54	3,280	840
830	10/20/93	83.4	6.42	3,260	858
863	10/20/93	81.8	6.53	3,300	822
893	10/20/93	81.0	6.41	3,300	856
923	10/21/93	79.6	6.55	3,460	836
955	10/21/93	81.9	6.37	3,370	824
986	10/21/93	83.4	6.18	3,190	782
1,017	10/21/93	86.1	6.36	3,100	810
1,048[a]	10/21/93	94.8	6.12	2,940	714
1,079	10/21/93	86.7	6.04	3,080	774
1,110	10/21/93	86.6	6.16	3,100	710
1,141	10/21/93	87.8	6.01	3,120	728
1,172.5	10/21/93	87.9	6.07	3,050	696
1,203	10/21/93	84.7	6.19	3,120	708
1,235	10/21/93	83.4	6.18	3,400	756
1,265	10/21/93	79.3	6.18	3,450	780
1,265[b]	10/21/93	82.2	6.19	3,440	760
1,297	11/1/93	75.9	6.82	3,160	820
1,327	11/1/93	75.9	6.55	3,340	858
1,358	11/1/93	74.8	6.45	3,510	810
1,389	11/1/93	75.4	6.30	3,460	690
1,421	11/1/93	75.5	5.62	3,460	826

Table 3 (Continued)

Depth (ft)	Date	Temperature (°F)	pH	Conductivity (μmhos/cm)	Chloride (mg/l)
1,421[c]	11/2/93	55.9	6.46	3,180	798
1,452	11/2/93	69.2	6.38	3,780	850
1,482	11/2/93	73.0	5.37	3,740	806
1,490[d]	11/2/93	80.1	6.32	3,480	788
1,490[e]	11/9/93	88.1	6.45	4,840	1,570
1,500[d]	11/2/93	83.4	6.13	6,100	1,760
1,514	11/30/93	81.1	6.57	6,200	1,895
1,544	12/1/93	82.7	6.52	6,230	2,145
1,576	12/1/93	84.6	6.11	9,280	2,830
1,606	12/1/93	83.4	6.09	9,940	3,750
1,637	12/1/93	81.7	5.06	10,220	3,800
1,647	12/1/93	82.9	6.27	10,310	3,560
1,660	12/1/93	83.0	6.16	10,380	3,500

Notes:
a) Sample sat in direct sun for ±30 minutes.
b) Sample taken after 1 hour of well development.
c) Repeat of sample obtained the previous night. Parameters determined about 1 hour after sampling.
d) Sample obtained from pilot hole prior to reaming and installation of 16-inch diameter casing.
e) Sample obtained after reaming hole but prior to installation of 16-inch diameter casing.

Table 4

SUMMARY OF FIELD WATER QUALITY TEST RESULTS CASING DISCHARGE FROM WELL IPW-2

Depth Range (ft)	Date	Temperature (°F)	pH	Conductivity (μmhos/cm)	Chloride (mg/l)
750 - 831	9/7/93	79.6	7.29	2,980	684
750 - 1047	9/7/93	83.4	6.56	3,110	750
750 - 1110	9/8/93	80.2	6.39	3,300	828
750 - 1172	9/8/93	87.6	6.32	2,950	792
750 - 1203	9/8/93	86.5	6.32	2,890	796
750 - 1265	9/8/93	83.6	6.57	3,050	710

Table 5

SUMMARY OF FIELD WATER QUALITY TEST RESULTS CASING DISCHARGE FROM WELL ICW-1

Depth Range (ft)	Date	Temperature (°F)	pH	Conductivity (μmhos/cm)	Chloride (mg/l)
730 - 1,330	9/14/93	80.4	6.52	3,140	734
730 - 1,525	9/15/93	81.9	6.21	4,360	1,330
1,487 - 1,514	10/13/93	82.4	6.58	6,810	2,640
1,487 - 1,531	10/13/93	87.3	6.25	6,670	2,500
1,487 - 1,545	10/13/93	90.3	6.10	6,370	2,280
1,487 - 1,577	10/13/93	87.7	6.15	6,320	2,360
1,487 - 1,608	10/14/93	84.3	6.09	8,250	3,300
1,487 - 1,640	10/14/93	85.7	5.84	10,510	3,550

Table 6

SUMMARY OF FIELD WATER QUALITY TEST RESULTS CASING DISCHARGE FROM WELL ICW-2

Depth Range (ft)	Date	Temperature (°F)	pH	Conductivity (μmhos/cm)	Chloride (mg/l)
740 - 800	10/20/93	84.5	6.52	3,280	836
740 - 863	10/20/93	81.2	6.46	3,300	830
740 - 893	10/20/93	81.2	6.15	3,310	854
740 - 923	10/21/93	80.7	6.40	3,380	914
740 - 1,500	11/2/93	81.1	5.85	4,500	1,220
1,478 - 1,576	12/1/93	84.7	5.64	7,810	2,580

Table 7

SUMMARY OF LABORATORY WATER QUALITY TEST RESULTS
DISCHARGE SAMPLES FROM UPPER PRODUCTION ZONE DURING APT IN WELL ICW-2

Date/Time	Chloride (mg/l)	Conductivity[a] (μmhos/cm)	pH[b]	pH[c]	Specific Gravity	TDS[d] (mg/l)	Temp.[e] (°C)
10/27/93 - 0942[f]	1,000	3,020	7.47	6.33	-	1,900	26.2
10/28/93 - 0220[g]	1,000	3,040	7.39	6.43	-	1,900	25.2
10/28/93 - 1259[h]	1,000	3,067	7.34	6.45	-	1,900	28.7
10/28/93 - 1326[i]	1,000	3,020	7.38	6.29	-	1,900	28.7

Notes:
a) Conductivity measured at 25 °C in the laboratory.
b) pH measured in the laboratory.
c) pH measured in the field.
d) TDS = Total Dissolved Solids.
e) Temperature measured in the field.
f) Sample collected 42 minutes after start of Upper Zone APT. Pumping rate = 1,200 gpm.
g) Sample collected 17.3 hours after start of Upper Zone APT. Pumping rate = 1,200 gpm.
h) Sample collected at discharge point into APT basin, about 28 hours after start of the Upper Zone APT. Pumping rate = 1,200 gpm.
i) Date sample collected reported in error as 10/29/93 instead of 10/28/93. Sample collected about 28.5 hours after start of the Upper Zone APT. Pumping rate = 1,200 gpm.

Table 8

SUMMARY OF LABORATORY WATER QUALITY TEST RESULTS
DISCHARGE SAMPLES FROM LOWER PRODUCTION ZONE DURING APT IN WELL ICW-2

Date/Time	Chloride (mg/l)	Conductivity[a] (μmhos/cm)	Conductivity[b] (μmhos/cm)	pH[c]	pH[d]	Specific Gravity	TDS[e] (mg/l)	Temp.[f] (°C)
12/14/93 - 1334[g]	3,400	10,200	8,500	7.28	6.18	1.0076	7,130	29.8
12/15/93 - 0845[h]	3,700	11,300	9,200	7.30	5.91	1.0076	7,391	28.0
12/16/93 - 0820[i]	3,900	11,200	9,100	7.32	5.54	1.0077	7,811	26.9

Notes:
a) Conductivity measured at 25 °C in the laboratory.
b) Conductivity measured in the field.
c) ph measured in the laboratory.
d) pH measured in the field.
e) TDS = Total Dissolved Solids.
f) Temperature measured in the field.
g) Sample collected 19 minutes after start of the Lower Zone APT. Pumping rate = 2,600 gpm.
h) Sample collected 19.5 hours after start of the Upper Zone APT. Pumping rate = 2,600 gpm.
i) Sample collected 43.1 hours after start of the Upper Zone APT. Pumping rate = 2,600 gpm.

are contained in Appendix C. Additional discussion of the geophysical logs is presented in Section 4.3.

The logging was performed by Southern Resource Exploration using portable truck-mounted equipment. Most of the logs were prepared using a digital format, although an analog format was used on a few occasions for caliper, flowmeter and temperature logging.

3.2.7 Casing Integrity Testing

With one exception, casing integrity tests were performed on each casing installed below the base of the Hawthorn Group. The exception was the 22-inch diameter casing installed in ICW-2. Testing was not performed on this casing because of the difficulty encountered in placing the annular seal in the well.

The procedure followed was similar for each test performed. The test was generally performed after the completion of grouting while the casing header (seal) assembly was still welded to the well casing. Water was pumped into the casing to a minimum pressure of 100 psi. The valves on the injection side of the well head were closed and the pressure decay was monitored with time; usually about one hour. Of the four tests attempted, only two (the tests on the 10-3/4-inch diameter casing in IPW-2 and the 16-inch diameter casing in ICW-2) were considered to have performed satisfactorily, as indicated by a decrease in pressure of less than 10 psi during a period of one hour. The other tests (in the 22-inch and 16-inch diameter casings in ICW-1) were terminated when the pressure could not be maintained, after several attempts, due to leakage through valves, threaded connections and/or fittings at the ground surface. The inability of the casing to maintain pressure was not considered to be a result of leakage from the casing joints.

3.2.8 Well Development and Flow Measurement

In general, the method of drilling for construction of the wells at the Indiantown site precluded the necessity for extensive well development upon completion of the work. The continuous removal of the drilling fluids and formation cuttings, without the addition or recirculation of materials to maintain hole stabilization, provided for removal of all but the finest-grained sediments. Clearing of the water with air lift assistance was relatively rapid, resulting in only a slight residual cloudiness, mainly from the compressed air.

Well IPW-2 was developed for a period of 6 hours. Well ICW-1 was developed for one hour and well ICW-2 was developed for one hour in the Upper Production Zone and one hour in the Lower Production Zone. Additional development occurred when the wells were allowed to flow at the surface.

Well flows were determined by a variety of methods. For most measurements, a horizontal section of open-ended 10-inch diameter Class 160 (SDR 26) PVC pipe of variable length attached to the Tee on the well head was used. The amount of open space (void) in the pipe was measured and the flow was estimated from a chart relating the void height to flow. Alternative methods used for flow estimation included the methods described in Appendix 16.E of Driscoll (1986) and Anderson (1967). Flows which were small enough to be confined to a hose were measured with a 150-gallon drum and a stopwatch.

Flow measurement for the APT was determined using 8-inch and 10-inch totalizing propeller flowmeters manufactured by Water Specialties Corp., which indicated production in gpm as well as total gallons produced during the testing. The flowmeters were installed in-line on horizontal sections of the discharge piping in close proximity to the well to facilitate observation.

The flowmeter and open discharge methods were also used, where appropriate, to measure flow during the flow tests performed on each well.

3.2.9 Aquifer Pumping Tests

Two APTs were conducted at the Indiantown site. The first test was performed following the completion of wells IPW-2 and ICW-1, when well ICW-2 was at an intermediate stage of construction (1,262.8 feet). The second test was performed after well ICW-2 was constructed to a final depth of 1,660 feet.

Well ICW-2 was used for the pumping well for both of the tests. A 10-inch vertical turbine pump, with bowls set about 50 feet below the well head, was used for ground water withdrawal. Sealing of the well, when not pumping, was done by welding a 22-inch diameter flange to the outside of the pump column and attaching it to the 22-inch diameter Tee on the well head. Check valves and gate and quick release valves were also used on the discharge piping downstream from the pump to control artesian flow from the pumping unit. Power for the pump was supplied by a diesel engine and right-angle gear drive on the pump.

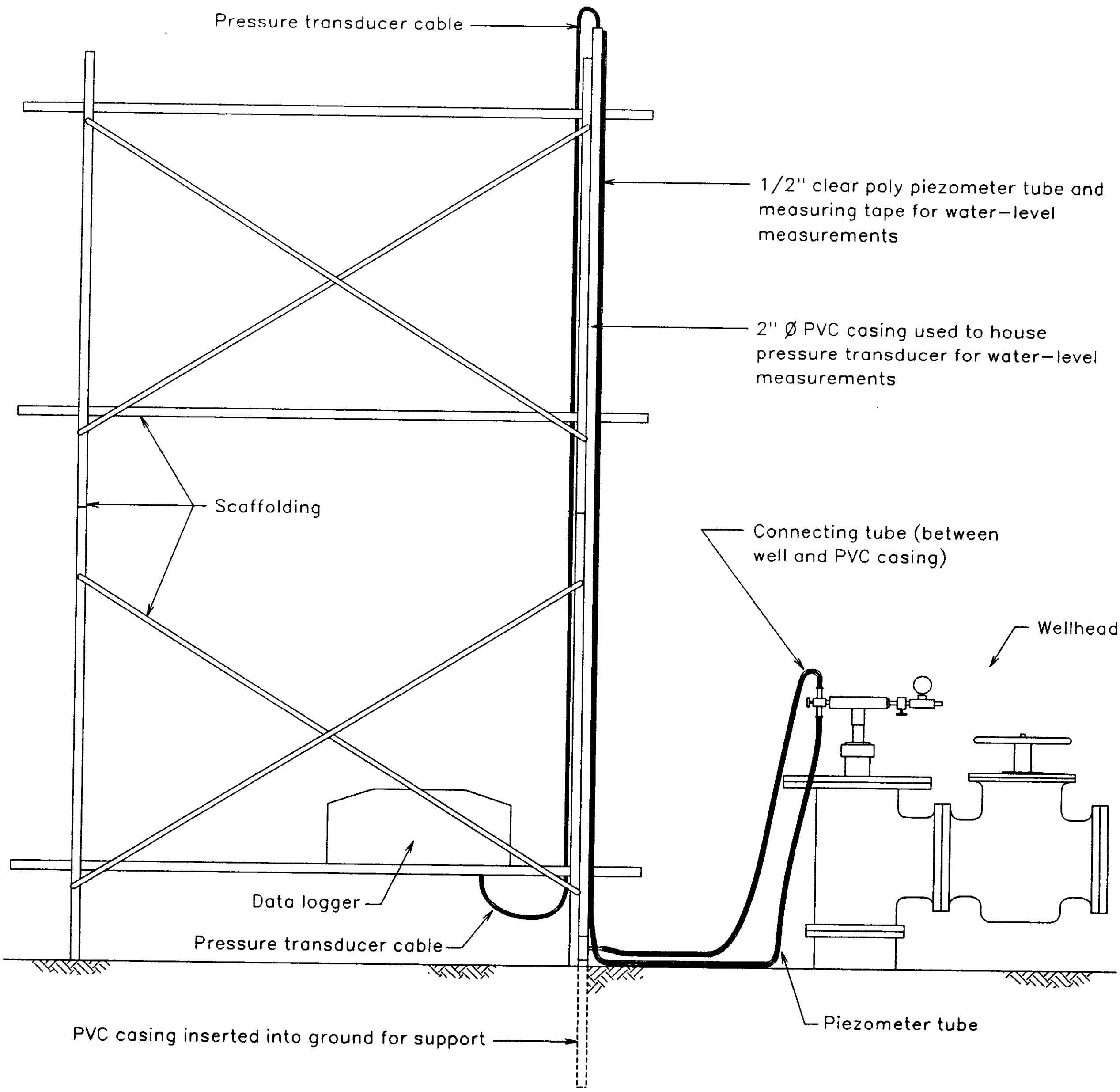
Pumping rates were measured by a Water Specialties Corp. totalizing propeller flowmeter as described in Section 3.2.8. Discharge from both tests was conveyed through buried plant piping to the APT storage basin at the southern end of the cooling water storage pond (Figure 1).

Water level measurements were made at the pumping well through two 2-inch diameter standpipes, extending about 18 and 10 feet above the well head, and 1/2-inch diameter clear poly tubing secured to the outside of the standpipe for use when water levels were above the ground surface. Direct reading of water level elevations above the ground surface was facilitated by placing a surveyors tape on the standpipe adjacent to the clear tubing and referencing a known elevation. Water levels were obtained manually during pumping using an electric hand-held water level meter manufactured by Soilinst, Inc. Water levels were also monitored prior to, during and following the pumping periods using a pressure transducer and data logger. The pressure transducer was positioned inside one of the standpipes which extended to a depth of about 45 feet below the top of the well.

Water levels were also monitored in wells IPW-1, IPW-2 and ICW-1 before, during and after each pumping test. A 2-inch diameter PVC standpipe, extending from about 3 feet below the ground surface to 17 to 20 feet above the ground surface, was set up at each well and connected to the monitoring port on the well head using poly tubing. A second section of clear poly tubing was connected to the monitoring port on the well head and attached to the outside of the standpipe. A surveyors tape was attached to the standpipe and referenced to a known elevation for direct water level readings. Water levels were also monitored using a transducer placed inside the standpipe and connected to a data logger. A diagram of the typical well installation is shown on Figure 5.

3.2.10 Well Surface Completion

Well IPW-1 was completed by installing a 10-inch diameter flanged Tee, gate valve, blind flanges, and monitoring points for piezometric head measurements and water quality sampling at the well head. Wells ICW-1 and ICW-2 were completed in a similar manner except that the Tee and gate valve are 16 inches in diameter. The concrete slabs around the base of each well will be constructed when the other surface facilities at the well site are completed. A diagram of the typical completed surface installation at the three wells is shown on Figure 6.



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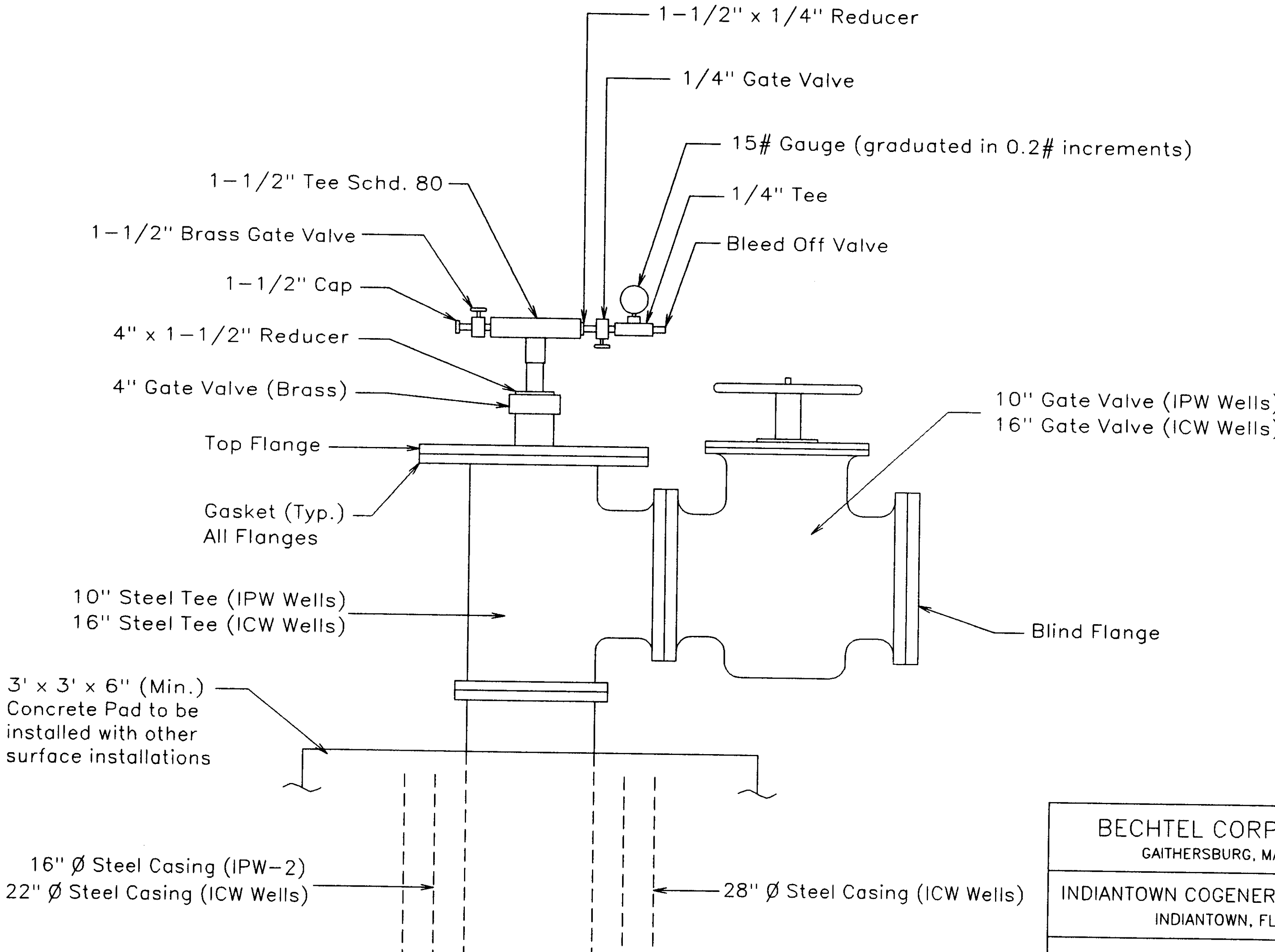
INDIANTOWN COGENERATION PROJECT
INDIANTOWN, FLORIDA

TYPICAL MONITORING SETUP
FOR AQUIFER PERFORMANCE TESTING

JOB NO.	FIGURE NO.	REV.
22019-001	FIGURE 5	0

Geotechnical & Hydraulic Engineering Services Drawing L:\INDTOWN\DC\WELLS\WLHDPIEZ.DW2



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BECHTEL CORPORATION GAITHERSBURG, MARYLAND		
INDIANTOWN COGENERATION PROJECT INDIANTOWN, FLORIDA		
WELLHEAD COMPLETION DETAILS		
JOB NO.	FIGURE NO.	REV.
22019-001	FIGURE 6	0

Geotechnical & Hydraulic Engineering Services Drawing L:\INDTOWN\DC\WELLS\WELLHEAD.DW2

4.0 DATA EVALUATION AND ANALYSES

4.1 Lithologic Logs

One of the objectives in performing the investigation at the Indiantown site was to confirm information on the thickness and lithology of the Upper and Lower Production Zones of the Upper Floridan aquifer developed from the drilling for and construction of well IPW-1 (Figure 1) in 1991. The stratigraphic relationships of the wells drilled in the current program were compared to determine if the materials beneath the Indiantown site are relatively uniform.

The lithologic logs of wells IPW-2, ICW-1 and ICW-2 (Appendix A) are based on the visual examination of drill cuttings obtained at 10-foot intervals during well construction. The materials penetrated by the wells range in age from Eocene to Holocene and include the stratigraphic units and elevations shown in Table 9.

Well IPW-2 is open to water bearing zones within the Suwannee Limestone, Ocala Limestone and the upper 435 feet of the Avon Park/Lake City Limestones, which comprise the Upper Production Zone of the Upper Floridan aquifer. Wells ICW-1 and ICW-2 are open to lower water bearing zones of the Avon Park/Lake City Limestones, which comprise the Lower Production Zone of the Upper Floridan aquifer. The top of this zone occurs at depths of between 660 and 670 feet below the base of the overlying Ocala Limestone. Well ICW-1 is open to the upper 153 feet of the Lower Production Zone while well ICW-2 is open to the upper 182 feet of the same zone.

While there are some minor differences in the elevations of the formation contacts (about ±20 feet), the logs of the wells indicate lithologies similar to those described for well IPW-1, allowing for some lateral variation and lensing within the formations (i.e., the presence of coarse sand lenses within the Peace River Formation in well IPW-2).

Table 9

INDIANTOWN SITE FLORIDAN AQUIFER WELLS FORMATIONS PENETRATED

FORMATION	WELL DEPTH/ELEVATION (Feet)/(Feet NGVD)			
	IPW-1	IPW-2	ICW-1	ICW-2
Fort Thompson/ Anastasia Fms.	0 to 81/+35 to -46	2 to 90/+32 to -56	3 to 80/+32 to -45	20 to 80/+18 to -42
Caloosahatchee Marl	81 to 120/-46 to -85	90 to 140/-56 to -106	80 to 140/-45 to -105	80 to 120/-42 to -82
Tamiami Fm.	120 to 168/ -85 to -133	140 to 170/ -106 to -136	140 to 180/ -105 to -145	120 to 150/ -82 to -112
Hawthorn Gp. - Peace River Fm.	168 to 680/ -133 to -645	170 to 680/ -136 to -646	180 to 680/ -145 to -645	150 to 670/ -112 to -632
Hawthorn Gp. - Arcadia Fm.	680 to 730/ -645 to -695	680 to 730/ -646 to -696	680 to 710/ -645 to -675	670 to 710/ -632 to -672
Suwannee Limestone	730 to 760/ -695 to -725	730 to 760/ -696 to -726	710 to 780/ -675 to -745	710 to 770/ -672 to -732
Ocala Limestone	760 to 820/ -725 to -785	760 to 830/ -726 to -796	780 to 820/ -745 to -785	770 to 820/ -732 to -782
Avon Park Limestone/ Lake City Limestone	820 to 1,702 (TD)[a]/ -785 to -1,667	830 to 1,265 (TD)/ -796 to -1,231	820 to 1,640 (TD)/ -785 to -1,605	820 to 1,660 (TD)/ -782 to -1,622

a) Bottom of well sealed below a depth of 1,340 feet by grouting.

Within the stratigraphic units comprising the water-bearing zones of the Upper Floridan aquifer, from the lower portion of the Hawthorn Group through the upper 820 feet of the Avon Park Limestone penetrated, the existence of two production zones can be confirmed as was postulated previously in 1991. At that time the areal extent of this zone was demonstrated by comparing lithologic similarities in well IPW-1 with LFM-1 at the FPL Martin plant about 3.8 miles northwest. Analysis of the logs and drilling observations from the installation of the present wells supports the previous work.

Separation of the two production zones by a confining layer is further supported by the dominance of chalky and shaley limestones and sandy limestones with low visible porosity in the interval from about El. -1,210 to about El. -1,460 feet.

As in well IPW-1, below El. -1,470 feet, the materials encountered are predominantly dolomite with lenses of sandy limestone. The dolomites exhibit moderate to high visible porosity to about El. -1,600 feet and low porosity below. This may be misleading, however, as the dolomites below El. -1,600 feet appear to be more highly fractured which increases the potential for small zones of very high production potential.

4.2 Water Quality

Water samples collected from the drill rod discharge were analyzed in the field for temperature, pH, conductivity and chloride at approximately 30-foot intervals as drilling advanced using the air rotary method (770 to 836 feet) in the three wells (Section 3.2.5). The results of the field analyses are shown in Tables 1 through 6. As indicated in Tables 1 through 3, conductivity and chloride values remained relatively consistent through depths of 1,490 to 1,510 feet during the drilling. Below these depths, chloride values increased by factors of 2 to 4 within the Lower Production Zone. In well ICW-1, another increase occurred at a depth of 1,640 feet. However, a similar increase was not present in well ICW-2 through a depth of 1,660 feet. Field testing (Tables 4 through 6) of the composite flow from all producing zones within the wells from the bottom of the casing to the drilled depth at the time of sampling support the drill stem analyses.

The field analyses of chloride and conductivity within the Upper Production Zone indicate little variation in quality within the zone in the three wells. This is somewhat different than the conditions encountered during drilling for well IPW-1 (Bechtel, 1991, Table 3), where variations of 200 to 400 mg/l of chloride were determined. Chloride values through the upper portion of the Zone to a depth of about 1,220 feet were lower than those detected in the three new wells.

The higher mineral content of the ground water samples taken from the three new wells in the Upper Production Zone could be due to locally poorer water quality or changes that have occurred in water quality since the construction of well IPW-1 in 1991.

Chloride and conductivity values within the Lower Production Zone (Tables 1 through 3) are relatively uniform through the portion of the zone penetrated. An indication of poorer quality water below a depth of 1,640 feet was detected in well ICW-1. A similar increase did not occur in well ICW-2, probably due to a lack of contribution to the overall well flow at this depth in the well.

4.3 Geophysical Logs

Geophysical logging was performed at various stages during the construction of wells IPW-2, ICW-1 and ICW-2 to support the lithologic logging, field chemical analysis, verification of flow zones, and adequate sealing of the cased intervals within each well. The geophysical logs are contained in Appendix C.

Aquifer and Flow Characteristics

The gamma, resistivity and acoustic logs show similar signatures defining the various lithologic changes which occur within the formations comprising the Surficial aquifer, predominantly clayey materials of the Hawthorn Group, limestones of the Suwannee and Ocala Limestones, and the dolomite beds within the Avon Park/Lake City Limestone.

Temperature and conductivity changes were encountered in the wells from a depth of about 750 feet through the producing intervals of the Upper Production Zone to a depth of about 1,200 to 1,250 feet. Little changes occur below this depth to about 1,480 to 1,510 feet (ICW-1 and ICW-2). Below this level, additional changes are noted in well ICW-1 to a depth of about 1,620 feet and in well ICW-2 to a depth of 1,625 feet.

Volumetric flow rate change occurs through various intervals in these wells in the Upper Production Zone through depths of about 1,220 feet. Little additional contribution is evident below this depth until the producing areas of the Lower Production Zone are encountered between 1,490 and 1,500 feet. Within the Lower Production Zone, contributions in flow are indicated in the intervals from 1,500 to 1,520 feet and 1,610 to 1,620 feet. Within well ICW-2, production from the Lower Production Zone is evident from a depth of about 1,490 feet through about 1,550 feet with very little contribution from below.

The production areas within wells IPW-2, ICW-1 and ICW-2 closely correspond to similar intervals within well IPW-1. Similar agreement is indicated in the temperature and fluid resistivity logs. Some variation is present in the resistivity logs which may be due to differences in the scale of logging.

Aquifer Sealing

No geophysical logging was performed during installation of the surface casing in these wells. The casing, 16-inch diameter in well IPW-2 and 28-inch diameter in the ICW wells, was set into the clay layers in the upper portion of the Hawthorn Group (Peace River Formation) and grouted-in-place, thus effectively sealing the Surficial aquifer.

Additional separation of the Surficial aquifer from the Upper Floridan aquifer is provided by the casings installed through the Hawthorn Group and into the Suwannee Limestone. In each well, caliper logs were run, after hole reaming, through the interval to be cased to verify the minimum hole diameter prior to casing installation. After casing installation and initial grout placement, a temperature log was run through the cased interval to verify grout placement. Because the interval grouted in well ICW-1 was relatively large (368 feet), a second temperature log was run following completion of the second stage of grouting. In well ICW-2, the temperature log indicated a lack of uniform grout placement attributed to channeling of the grout during pumping. Therefore, additional grouting was performed in the upper portion (0 to 177 feet) of the annulus between the 22- and 28-inch diameter casings (Section 3.2.4).

Caliper logs were also run through the reamed intervals in the ICW wells (1,490 feet in well ICW-1 and 1,484 feet in well ICW-2) prior to installation of the 16-inch diameter casing to seal the Upper Production Zone from the Lower Production Zone. The log was run to verify the minimum hole diameter for casing installation. Temperature logs were run on the initial grout stage to verify the uniformity of placement. A temperature log was also performed following the final stage of grouting (between the 16-inch and 22-inch diameter casings) to verify uniform grout placement between the two casings. The temperature log of well ICW-2, run following the last stage of grouting, clearly indicates changes in temperature closely corresponding to each of the six stages of grouting. This demonstrates the uniformity of grout placement throughout the length of the 16-inch diameter casing and the existence of an effective seal between the Upper and Lower Production Zones.

Additional documentation of aquifer sealing between the various cased intervals is provided by the cement bond logs. The logs were run though all of the cased intervals below the Surficial aquifer except for the 22-inch diameter casing in well ICW-2.

4.4 Aquifer Performance Tests

Two APTs were conducted in the Upper Floridan aquifer - one in the Upper Production Zone and the other in the Lower Production Zone - in order to determine the transmissivity and storage coefficient of each of the two zones and to determine the leakage coefficient between the zones.

For both tests, well ICW-2 was pumped at a constant rate while measuring changes in water levels in wells ICW-1, IPW-1 and IPW-2. The Upper Production Zone test was conducted prior to the completion of well ICW-2, when the uncased portion of the borehole (738.7 to 1,262.8 feet) penetrated only that zone. Following the completion of well ICW-2 in the Lower Production Zone, the second APT was conducted in that zone from a depth of 1,477.8 to 1,660 feet. The open intervals of the wells and the relative distances between them are illustrated on Figure 7.

4.4.1 Upper Production Zone APT

For the Upper Production Zone APT, well ICW-2 was pumped for a period of 29 hours beginning at 9:00 AM on October 25, 1993, and ending at 2:00 PM on October 26. The test was terminated with the concurrence of the SFWMD (Bechtel, 1993a) when preliminary analysis of the data collected indicated that drawdown equilibrium had been achieved.

Water was withdrawn from well ICW-2 using a turbine pump placed at a depth of approximately 50 feet inside the well and powered at the ground surface by a diesel engine. In accordance with the APT Work Plan, the pumped water was discharged to the APT basin at the southern end of the cooling water storage pond (Figure 1).

Pumping Rate Monitoring

The pumping rate was measured using a totalizing flowmeter attached to the discharge pipe. Based on the totalizing flowmeter readings, provided in Appendix D, the average pumping rate during the test was determined to be 1,194 gpm.

Water Level Monitoring

Ground water levels were measured at wells ICW-1, ICW-2, IPW-1 and IPW-2 using data loggers and pressure transducers. Measurements were begun 7 days before the start of the test at well IPW-1 and two days before the start of the test at wells ICW-1, ICW-2 and IPW-2. The measurements continued for approximately 19 hours after the pump was shut off. Hydrographs of the measured water levels are shown on Figure 7 and the measured values are tabulated in Appendix D.

The pressure transducers were placed inside a 2-inch diameter PVC standpipe, which extended from approximately 3 feet below the ground surface to approximately 17 feet above the ground surface at wells IPW-1, IPW-2 and ICW-1 and from approximately 45 feet below the ground surface to 20 feet above the ground surface at well ICW-2. Inside the standpipe, the transducers were set approximately 10 feet below the pre-test piezometric surface at wells ICW-1 and IPW-2 and approximately 50 feet below the pre-test piezometric surface at well ICW-2. A Hermit[tm] model 1000C data logger, manufactured by In-Situ, Inc. of Laramie, Wyoming, was used to measure ground water levels at well IPW-1 while water levels at wells ICW-1, ICW-2 and IPW-2 were measured using pressure transducers and Stevens model 420 data loggers manufactured by Leupold and Stevens, Inc. of Beaverton, Oregon.

In order to verify the pressure transducer/data logger measurements, as well as providing back-up data in case the electronic equipment failed, ground water levels in both the Upper and Lower Production Zones were measured visually using manometers. The manometers were constructed using transparent vinyl tubing attached to a valve at the wellhead and supported by the PVC standpipe. Surveying tape was positioned next to the vinyl tubing so that the ground water elevation could be read directly from the vinyl tubing. Except at the pumping well, the piezometric surface never dropped below the ground surface, thus allowing the manometers to be used throughout the entire test.

At well ICW-2, where water levels did drop below the ground surface during pumping, a second standpipe was installed with a stickup of approximately 10 feet. A valve at the wellhead was kept closed to prevent flow out of the standpipe until the piezometric surface dropped below the top of the well. During pumping, water levels in well ICW-2 were measured using an electric hand-held water level meter manufactured by Solinst Canada, Ltd of Glen Williams, Ontario, Canada.

Barometric Pressure Monitoring

Barometric pressure measurements at well IPW-1 were begun 7 days before the start of the APT using the Hermit^{tm} data logger and a pressure transducer designed to measure barometric pressure. The measured values are tabulated in Appendix D and are illustrated with the water levels on Figure 7.

Barometric pressure fluctuations did appear to influence water levels. However, because of the cyclic nature of the fluctuations and because the water level variations in wells IPW-1 and IPW-2 caused by the barometric pressure fluctuations was considerably less than the observed responses caused by pumping from well ICW-2 and other pumping in the region, it was determined that an adequate analysis of the data could be performed without making corrections for the influence of barometric pressure changes.

Test Analysis and Results

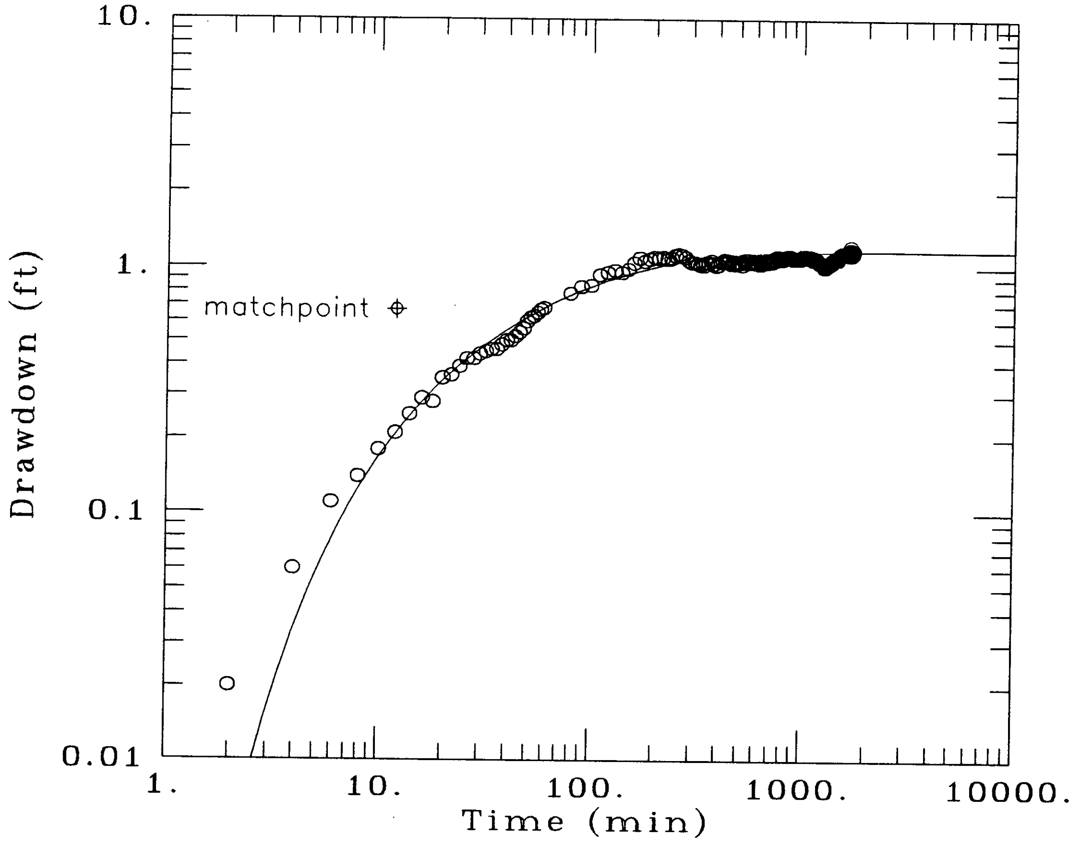
Ground water level drawdown responses at wells IPW-1 and IPW-2 to pumping at well ICW-2 were analyzed using the type curve method introduced by Hantush and Jacob (1955) for determining the transmissivity, storage coefficient and leakage coefficient in a leaky confined aquifer. The type curves used in this method of analysis are based on an analytical solution to the ground water flow equation for non-steady, radial flow to a well fully penetrating a confined aquifer in which the water "leaks" into the aquifer through a semi-confining layer from an overlying and/or underlying aquifer. The analysis method assumes that no water is released from storage in the semi-confining layer and that the drawdown in the underlying and/or overlying aquifer is insignificant.

The recovery of the ground water level in well ICW-2, after the pump was shut off, was analyzed using the Theis Recovery method of analysis discussed in McWhorter and Sunada (1977). Because the affect of leakage would violate the assumptions of the analysis, the Theis Recovery method of analysis was not used to analyze recoveries at wells IPW-1 and IPW-2. However, the affect of leakage on drawdown diminishes with decreasing distance from the pumped well and becomes negligible at well ICW-2, making the Theis Recovery method valid at that well.

The water level variations in well ICW-1 appear to have been caused entirely by barometric pressure fluctuations and pumping from wells other than ICW-2. No correlation between the water level variations in this well and pumping from well ICW-2 could be discerned and, therefore, no analysis was performed on the data collected from this well.

Both the Hantush and Jacob and Theis Recovery analyses were facilitated using the computer program AQTESOLV (Version 1.1, Release 4), developed by Geraghty and Miller, Inc. AQTESOLV is an interactive menu-driven computer program which combines statistical parameter estimation methods with graphical curve-matching techniques for analysis of aquifer test data.

Log-scale graphs of drawdown versus time and the fitted Hantush and Jacob method type curves are shown on Figures 8 and 9 for wells IPW-1 and IPW-2, respectively, and the computed transmissivities and storage and leakage coefficients are shown in Table 10.



Test Parameters

Pumping Rate = 1193 gpm

Distance From Pumped Well = 2468 ft

Curve–Match Parameters

time = 12 min for u = 1

drawdown = 0.67 ft for W(u,r/B) = 1

r/B = 0.55

Hydrologic Parameters

Transmissivity = 205,000 gpd/ft

Storage Coefficient = 0.00015

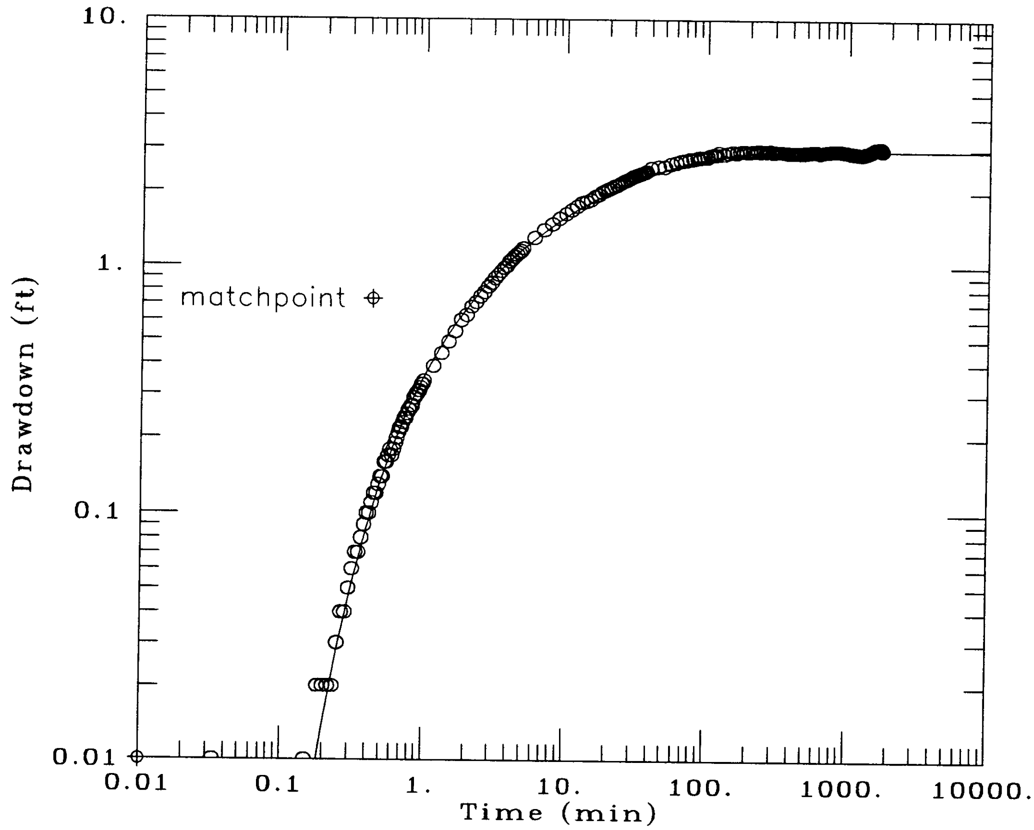
Leakage Coefficient (K'/b') = 0.0014 day^{-1}

EXPLANATION

○ Measured Drawdown

Fitted Type Curve
(after Hantush and Jacob, 1955)

BECHTEL POWER CORPORATION GAITHERSBURG, MARYLAND		
INDIANTOWN COGENERATION PROJECT INDIANTOWN, FLORIDA		
IPW–1 Drawdown and Fitted Type Curve Upper Production Zone APT		
JOB NO.	FIGURE NO.	REV.
22019	8	0



Test Parameters

Pumping Rate = 1193 gpm

Distance From Pumped Well = 365 ft

Curve–Match Parameters

time = 0.53 min for u = 1

drawdown = 0.67 ft for W(u,r/B) = 1

r/B = 0.125

Hydrologic Parameters

Transmissivity = 205,000 gpd/ft

Storage Coefficient = 0.0003

Leakage Coefficient (K'/b') = 0.0032 day^{-1}

EXPLANATION

○ Measured Drawdown

Fitted Type Curve (after Hantush and Jacob, 1955)

BECHTEL POWER CORPORATION GAITHERSBURG, MARYLAND		
INDIANTOWN COGENERATION PROJECT INDIANTOWN, FLORIDA		
IPW–2 Drawdown and Fitted Type Curve Upper Production Zone APT		
JOB NO.	FIGURE NO.	REV.
22019	9	0

Table 10

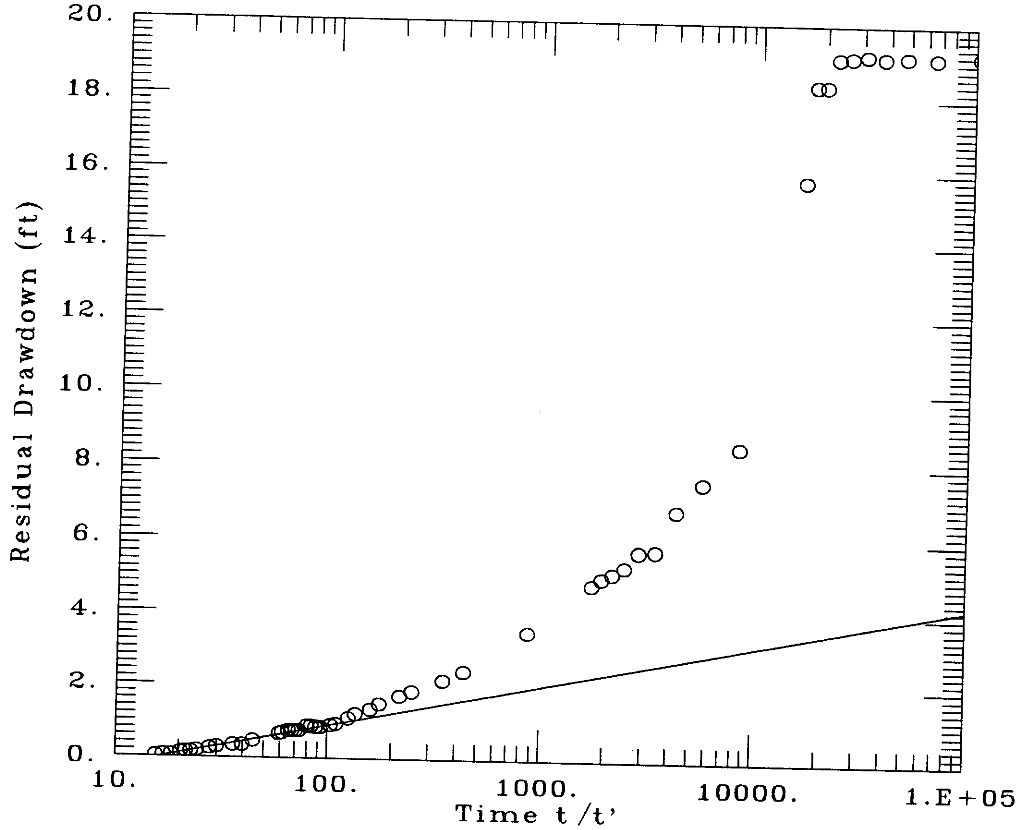
HYDROGEOLOGIC PARAMETERS DETERMINED FROM UPPER PRODUCTION ZONE AQUIFER PERFORMANCE TEST DATA

Well No.	Transmissivity (gpd/ft)	Storage Coefficient (dimensionless)	Leakage Coefficient (day^{-1})
IPW-1	205,000	0.00015	0.00014
IPW-2	205,000	0.0003	0.00032
ICW-2	290,000	not determined	not determined

The residual drawdown data and fitted straight line for the recovery analysis is also shown on Figure 10 and the computed transmissivity is also shown in Table 10. Note that the storage and leakage coefficients generally cannot be computed using the Theis method for analyzing pumping test recovery data.

A transmissivity of 205,000 gpd/ft, a storage coefficient of 0.0003 (dimensionless), and a leakage coefficient of 0.0032 day^{-1}, determined from analysis of the well IPW-2 test data, are recommended for use in computing potential impacts to area water users. The recommendation is based on the better fit of the type curve to the data at that well, which is attributed to the proximity of well IPW-2 to the pumped well. The more pronounced effect of pumping on water level responses at well IPW-2 diminishes the influences of regional pumping, barometric pressure changes, and/or other external affects. The transmissivity computed from the recovery data at well ICW-2 is intended to be more of a check for reasonableness. However, because the transmissivity computed from the well ICW-2 recovery data is influenced primarily by aquifer conditions immediately surrounding the well, it is less indicative of site and/or regional scale hydrogeologic conditions than the transmissivity computed using the test data from well IPW-2.

The leakage coefficient is assumed to be indicative almost entirely of permeability conditions in the semi-confining layer separating the Upper and Lower Production Zones of the Upper Floridan aquifer. While some leakage does occur between the Upper Floridan and Surficial aquifers through the Hawthorn Group, the leakage coefficient between these two aquifers - estimated to be between 0.000001 day^{-1} to 0.00005 day^{-1} (Tibbals, 1990) – is too small to have affected the test results. The leakage coefficients for the Hawthorn Group are published values for an area 20 to 30 miles north of the site estimated from regional modeling analyses in east-central Florida.



Test Parameters

Pumping Rate = 1193 gpm

Total Pumping Time = 1740 min

Slope of Fitted Line

Δs/log cycle = 1.09 ft

Hydrologic Parameters

Transmissivity = 290,000 gpd/ft

EXPLANATION

○ Measured Residual Drawdown

/ Fitted Straight Line (after Theis, 1945)

BECHTEL POWER CORPORATION GAITHERSBURG, MARYLAND		
INDIANTOWN COGENERATION PROJECT INDIANTOWN, FLORIDA		
ICW–2 Residual Drawdown and Fitted Line Upper Production Zone APT		
JOB NO.	FIGURE NO.	REV.
22019	10	0

4.4.2 Lower Production Zone APT

For the Lower Production Zone APT, well ICW-2 was pumped for a period of 44 hours beginning at 1:15 PM on December 14, 1993, and ending at 9:15 AM on December 16. After pumping for 26 hours, the total duration of the test and the results of a preliminary analysis of the data collected was discussed with the SFWMD (Bechtel, 1993b).

Water was withdrawn from well ICW-2 using a turbine pump placed at a depth of approximately 50 feet inside the well and powered at the ground surface by a diesel engine. As with the Upper Production Zone APT, the pumped water was discharged to the APT basin at the southern end of the cooling water storage pond (Figure 1).

Pumping Rate Monitoring

The pumping rate was measured using a totalizing flowmeter attached to the discharge pipe. Based on the totalizing flowmeter readings, provided in Appendix E, the average pumping rate during the test was 2,627 gpm. No significant changes in the pumping rate occurred during the test.

Water Level Monitoring

Ground water levels were monitored at wells ICW-1, ICW-2, IPW-1 and IPW-2 using data loggers and pressure transducers. The measurements were begun 5 days before the start of the test and were stopped approximately 12 hours after the pump was shut off. Hydrographs of the measured water levels are shown on Figure 11 and the measured values are tabulated in Appendix E.

The water level monitoring equipment used during the Lower Production Zone test was identical to that used during testing of the Upper Production Zone. As with the first test, visual and manual measurements were made to verify the accuracy of the pressure transducers/data loggers and provide backup in case the electronic equipment failed.

Barometric Pressure Monitoring

The barometric pressure was measured at well IPW-1 beginning 5 days before the start of the APT using a pressure transducer and Hermit^{tm} 1000C data logger. The barometric pressure values are tabulated in Appendix E and are shown with the water level hydrographs on Figure 11.

No corrections for the effects of barometric pressure fluctuations on water levels in the wells were made. Because the changes in water levels caused by barometric pressure fluctuations were cyclic in nature, it was determined that an analysis of the data from well ICW-1 could be performed adequately without making corrections for the influence of barometric pressure. For the Upper Production Zone wells, it was judged that even if corrections for barometric pressure fluctuations were made, any responses caused by pumping from well ICW-2 would still be too small to produce a reasonable analysis.

Test Analysis and Results

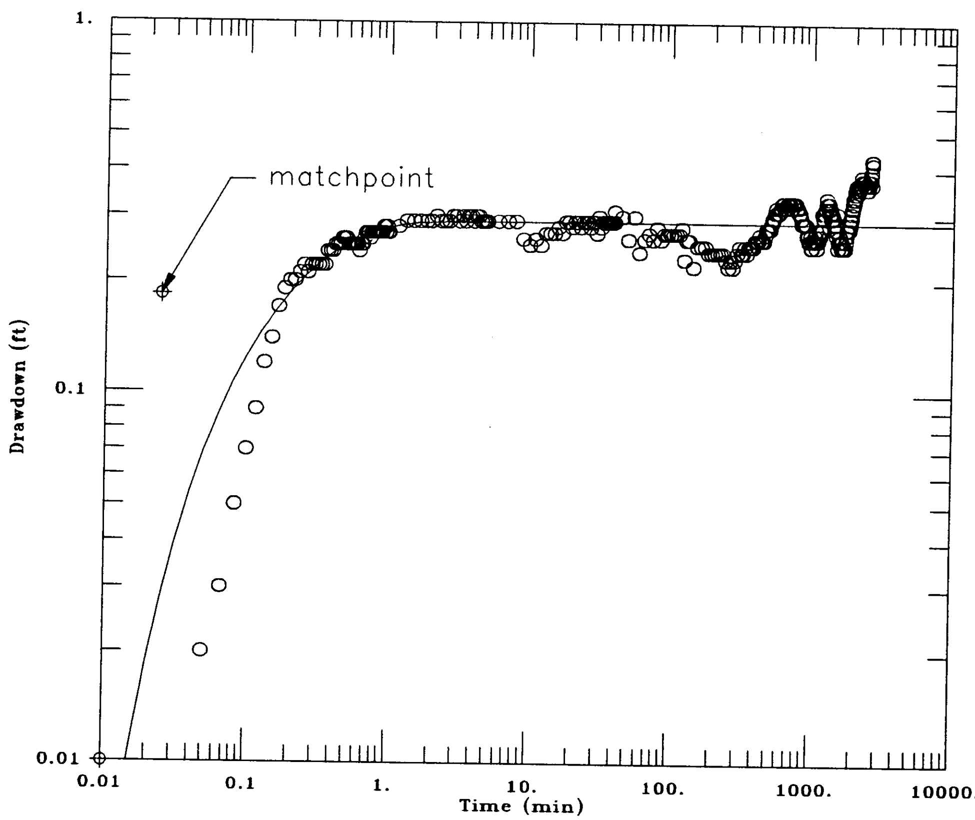
The ground water level drawdown response at well ICW-1 to pumping at ICW-2 was analyzed using the Hantush and Jacob (1955) type curve method. As with the Upper Production Zone APT, the recovery of ground water levels at well ICW-2 was analyzed using the Theis recovery method. No measurable water level responses to pumping at well ICW-2 were detected at either of the two Upper Production Zone wells (IPW-1 and IPW-2) and so no analyses were performed using the water level data collected at these wells.

Ground water levels dropped during the period of the test, most likely as a result of regional pumping. Because changes in water levels caused by external influences are not accounted for in either of the test analysis methods, these changes were factored out of the water levels in wells ICW-1 and ICW-2. To estimate the water levels that would have occurred had well ICW-2 not been pumped, a polynomial (of degree 2) was fit to the water levels measured immediately before the start of the test and those measured after recovery in wells ICW-1 and ICW-2. The estimated water levels are shown on the hydrographs for wells ICW-1 and ICW-2 on Figure 11 as dashed lines. Drawdown in well ICW-1 and residual drawdown in well ICW-2 were then computed by subtracting the measured water levels from those computed using the polynomial equations.

A log-scale graph of drawdown versus time and the fitted Hantush-method type curves are shown on Figure 12 for well ICW-1. The transmissivity was determined to be 2,300,000 gpd/ft and the storage and leakage coefficients were determined to be 0.00013 (dimensionless) and 0.3 day^{-1}, respectively.

The residual drawdown data and fitted straight line for the recovery analysis is shown on Figure 13. The transmissivity was computed to be 2,300,000 gpd/ft using the Theis recovery analysis method. The high leakage coefficient determined from the Lower Production Zone test data is almost 100 times greater than that determined from the Upper Production Zone test data and indicates that an additional zone of high transmissivity probably exists below the open intervals in wells ICW-1 and ICW-2. Based on the shape of the drawdown curve shown on Figure 12, this high transmissivity zone appears to be a distinct hydrogeologic unit separated by a semi-confining layer from the zone in which wells ICW-1 and ICW-2 are open. The curve is considered to be more indicative of two separate zones than would be one indicating partial penetration of the wells into a thicker zone. Also, wells ICW-1 and ICW-2 are considered to be sufficiently far apart to remove any influences of partial penetration from the test data.

In order to verify the hypothesis that a highly transmissive zone exists below the completed depths of wells ICW-1 and ICW-2, a three-dimensional modeling analysis of the pumping test was performed using the ground water flow model MODFLOW (McDonald and Harbaugh, 1988). The results of the modeling analysis show that if a leakage coefficient of



<u>Test Parameters</u>

Pumping Rate = 2627 gpm

Distance From Pumped Well = 408 ft

<u>Curve-Match Parameters</u>

time = 0.025 min for u = 1

drawdown = 0.13 ft for W(u,r/B) = 1

r/B = 0.40

<u>Hydrologic Parameters</u>

Transmissivity = 2,300,000 gpd/ft

Storage Coefficient = 0.00013

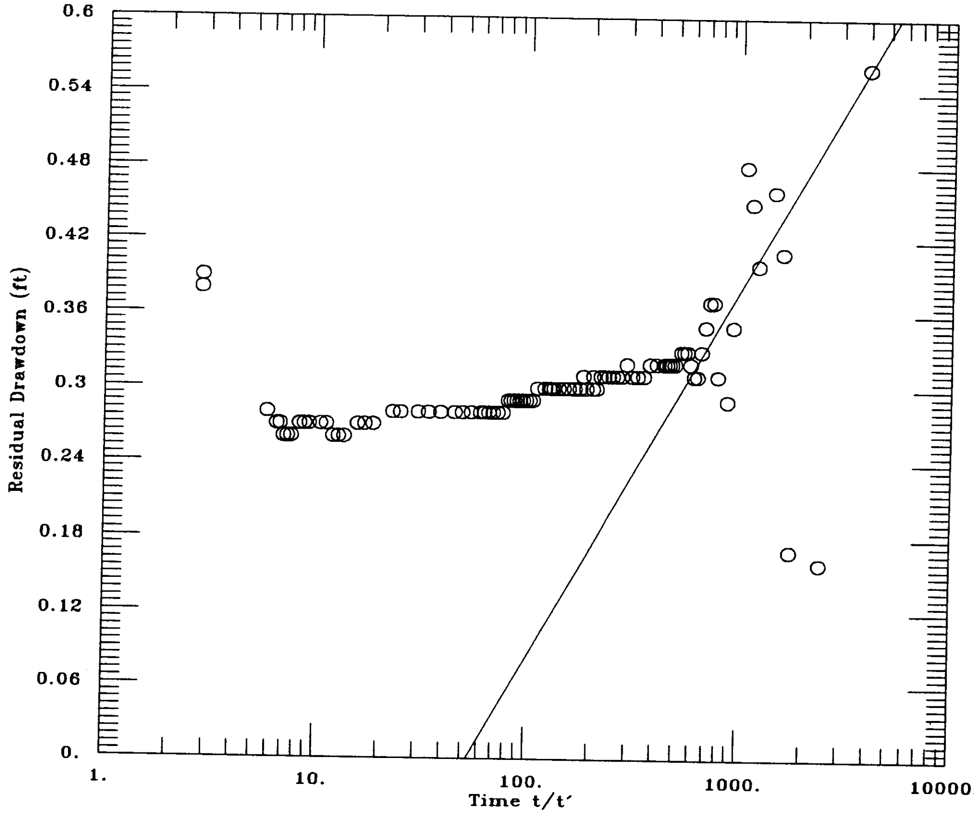
Leakage Coefficient (K'/b') = 0.3 day^{-1}

EXPLANATION

○ Measured Drawdown

Fitted Type Curve (after Hantush and Jacob, 1955)

BECHTEL POWER CORPORATION GAITHERSBURG, MARYLAND		
INDIANTOWN COGENERATION PROJECT INDIANTOWN, FLORIDA		
ICW-1 Drawdown and Fitted Type Curve Lower Production Zone APT		
JOB NO.	FIGURE NO.	REV.
22019	12	0



Test Parameters

Pumping Rate = 2627 gpm

Total Pumping Time = 2640 min

Slope of Fitted Line

Δs/log cycle = 0.3 ft

Hydrologic Parameters

Transmissivity = 2,300,000 gpd/ft

EXPLANATION

○ Measured Residual Drawdown

Fitted Straight Line (after Theis, 1945)

BECHTEL POWER CORPORATION GAITHERSBURG, MARYLAND		
INDIANTOWN COGENERATION PROJECT INDIANTOWN, FLORIDA		
ICW–2 Residual Drawdown and Fitted Line Lower Production Zone APT		
JOB NO.	FIGURE NO.	REV.
22019	13	0

0.3 existed between the Upper and Lower Production Zones, a much greater change in water levels would have been detected in the Upper Production Zone at well IPW-2. The analysis also indicates that the transmissivity of the highly permeable zone underlying the Lower Production Zone would have to be much greater – possibly 10 times or more higher - than that determined by the Lower Production Zone APT.

The Lower Production Zone wells were purposefully not drilled deeper to avoid higher salinity water, which was encountered below El. -1,640 feet during the exploratory drilling at well IPW-1 (Bechtel, 1991).

5.0 GROUND WATER WITHDRAWAL IMPACT ANALYSIS

5.1 Purpose

A hydrogeologic impact model was constructed to determine if flow rates from area wells would be adversely impacted as a result of ground water withdrawals from the Upper Floridan aquifer by the Indiantown Cogeneration Plant. Impacts were calculated for all permitted wells open to the Upper Floridan aquifer within a 5-mile radius of the Indiantown Cogeneration Plant site.

5.2 Area Wells

Wells with permits from the SFWMD that are completed in the Upper Floridan aquifer within a 5-mile radius of the site are shown on Figure 14, taken from the Upper Floridan Aquifer Hydrogeologic Investigation Report (Bechtel, 1991), previously submitted to the SFWMD. The names of the owners of the wells, taken from the same report, are presented in Table 11.

5.3 Basis for Impact

SFWMD regulations (1985) require that new wells cannot reduce the withdrawal capability of any existing permitted well by more than 10 percent. For free-flowing wells such as those completed in the Upper Floridan aquifer, the withdrawal capability is influenced primarily by two factors:

1) the height of the piezometric surface above the ground surface; and

2) the head-loss caused by friction as water flows through the well (also known as friction loss).

Table 11

PERMITTED FLORIDAN AQUIFER USERS WITHIN A 5-MILE RADIUS OF THE ICL SITE

Identification No.[1]	Permit No.	Water Allocation Annual/Max. Month (mil. gal.)	Owner/Permitee and Description
3	43-00028	28.52/10.5	**Byron E. Grant.** One well to a depth of 1,300 feet flowing at 1,000 gpm.
7	43-00071	57.49/-	**Joseph D. Farish, Jr.** One well to a depth of 1,150 feet.
13	43-00122	3,099.97/1,140.96	**Caulkins Land Develop., Ltd.** Four surface water withdrawals from C-44 (2 @ 20,000 gpm and 2 @ 25,000 gpm). Eight wells at depths up to 1,340 feet and capacities up to 1,500 gpm (1 @ 800, 2 @ 850, 1 @ 975, 1 @ 1,050, 1 @ 1,275, 1 @ 1,450, and 1 @ 1,500 gpm).
14	43-00159	49.21/18.11	**Sullivan & Huffman.** One well to a depth of 1,496 feet with a capacity of 720 gpm.
15	43-00172	73.59/27.09	**T & T Enterprises.** One well to a depth of 1,210 feet flowing at 800 gpm.
21	43-00260	89.84/14.22	**Indianwood Assoc., Ltd.** Three surface water withdrawals from onsite lakes (2 @ 400 gpm and 1 @ 200 gpm). One well to a depth of 1,000 feet with a capacity of 800 gpm.

Table 11 (Continued)

Identification No.[1]	Permit No.	Water Allocation Annual/Max. Month (mil. gal.)	Owner/Permitee and Description
23	43-00362	50.0/- (Max. Daily = 0.2)	**Caulkins Indiantown Citrus Co.** Two wells to a depth of 175 feet, each with a capacity of 60 gpm. One well to a depth of 1,240 feet flowing at 550 gpm.
28	43-00501	15.27/-	**Howard F. Fennel.** One well to a depth of 1,000 feet with an estimated flow of 310 gpm.
29	43-00503	11.29/-	**Howard F. Fennel.** One well to a depth of 1,000 feet with an estimated flow of 310 gpm.
47	43-00625	253.89/93.45 (Max. Monthly from Floridan aquifer only = 9.33)	**VIA Tropical Fruits, Inc.** Four surface water withdrawals from onsite retention area, each with a capacity of 1,700 gpm. Ten wells to a depth of 120 feet, each with a capacity of 300 gpm. One well to a depth of 1,100 feet flowing at 400 gpm.

[1]See Figure 14 for location of corresponding number.

Source of Data: South Florida Water Management District

At first, in order to simplify the initial impact analysis, only changes to the piezometric surface were considered. By ignoring friction loss, the percent reduction in the withdrawal capability of a well can be equated to the percent reduction in the height of the piezometric surface above the ground surface. Therefore, a 10 percent decrease in the height of the piezometric surface can be considered equal to a 10 percent decrease in the flow rate. The ground surface and Upper Floridan aquifer piezometric surface elevations at permitted wells located within a 5-mile radius of the Indiantown Cogeneration Plant site are shown in Table 12, taken from Bechtel (1991).

As a result of ignoring friction loss, the impacts on area wells are considered to be overestimated. In reality, a 10 percent decrease in the piezometric surface will result in a less than 10 percent decrease in the withdrawal capability of a well because, as the flow rate from a well decreases, the friction loss also decreases which reduces its effect on the well's withdrawal capability. Therefore, where the calculated drawdown exceeded the allowable impact based solely on the relationship between the piezometric and ground surfaces, an additional calculation was made to consider the effect of the reduction in friction loss.

5.4 Impact Model

Ground water level declines in the Upper Floridan aquifer caused by ground water withdrawals at the Indiantown Cogeneration Plant site were calculated using the computer program MODFLOW, a three-dimensional finite-difference ground water flow model developed by the U.S. Geological Survey (McDonald and Harbaugh, 1988).

Withdrawal Scenarios

The impact analysis was performed for two ground water withdrawal scenarios. The first scenario considered two wells withdrawing ground water continuously at a total rate of 300 gpm from the Upper Production Zone and four wells withdrawing at a total rate of 3,097 gpm from the Lower Production Zone for a period of 75 consecutive days. This scenario is

Table 12

GROUND AND PIEZOMETRIC SURFACE ELEVATIONS AND ALLOWABLE DRAWDOWNS AT PERMITTED WELLS WITHIN A 5-MILE RADIUS OF THE ICL SITE

I.D. Number	Permit Number	Owner	Ground Surface Elevation (ft msl)	Upper Floridan Aquifer Piezometric Elevation (ft msl)	Height of Piezometric Surf. above Ground Surf. (ft)	Allowable Drawdown (ft)
3	43-00028	Byron Grant	25	48.2	23.2	2.32
7	43-00071	Farish	27	48.2	21.2	2.12
13a	43-00122-I-1	Caulkins Land Development	25	48.5	23.5	2.35
13b	43-00122-I-2	Caulkins Land Development	25	48.4	23.4	2.34
13c	43-00122-I-3	Caulkins Land Development	25	48.3	23.3	2.33
13d	43-00122-I-4	Caulkins Land Development	25	48.3	23.3	2.33
13e	43-00122-I-5	Caulkins Land Development	25	48.3	23.3	2.33
13f	43-00122-II-1	Caulkins Land Development	25	48.4	23.4	2.34
13g	43-00122-II-2	Caulkins Land Development	25	48.5	23.5	2.35
13h	43-00122-II-3	Caulkins Land Development	25	48.5	23.5	2.35
14	43-00159	Sullivan & Huffman	34	48.4	14.4	1.44
15	43-00172	T & T Enterprises	27	48.3	21.3	2.13
21	43-00260	Indianwood	40	48.7	8.7	0.87
23	43-00362	Caulkins Indiantown Citrus	34	48.4	14.4	1.44
28	43-00501	Fennel	34	48.3	14.3	1.43
29	43-00503	Fennel	37	48.4	11.4	1.14
47	43-00625	VIA Tropical Fruits	40	48.5	8.5	0.85

based on the maximum daily withdrawal allocation contained in the COC. The second scenario is based on withdrawing ground water at rates of 300 and 2,597 gpm from the Upper and Lower Production Zones, respectively, for a period of 90 days. This scenario is based on the maximum annual allocation also contained in the COC.

Model Grid

The model grid encompasses a square area roughly 115 miles on a side with the Indiantown cogeneration plant site at its center. Such a large area was chosen so that the model boundaries would not affect drawdown estimates. There were no hydrogeologic features (e.g. rivers or discernable principle anisotropy directions) to serve as a basis for aligning the model grid. Therefore the grid was arbitrarily aligned with the state grid system. Finite-difference cell sizes in the plant area were uniformly set at 100 feet by 100 feet. Outside the plant site, the cells were increasingly expanded in size to the edge of the model.

The model was divided, vertically, into three layers as shown on Figure 15. The uppermost layer represents the Surficial aquifer, and the middle and lower layers represent the Upper and Lower Production Zones, respectively, of the Upper Floridan aquifer.

As discussed in Section 4.4.2, the APT in the Lower Production Zone yielded evidence for the existence of a highly transmissive zone below the Lower Production Zone. Because of the difficulty in assigning hydrogeologic properties to this zone, it was not considered in the impact model. By not considering this zone, impacts computed by the model are considered to be overpredicted.

Hydrogeologic Parameters

The hydrogeologic parameters used in the impact model are illustrated on Figure 15, along with references regarding their sources. Most of the hydrogeologic parameters were based on the results of the APTs performed in the Upper and Lower Production Zones. However,

Model Layer	Hydrogeologic Parameters	Hydrogeologic Unit		Geologic Formation
1	T = 5600 gpd/ft (From Table 2.3.2-2 of Site Certification Application) S_y = 0.32 (From Table 2-2 of McWhorter and Sunada, 1977)	Surficial Aquifer		Fort Thompson/Anastasia Fm. Caloosahatchee Marl Tamiami Fm.
	K'/b' = 0.00001 day^{-1} (Intermediate within range of values presented on Figure 30 of Tibbals, 1990)	Confining Layer		Hawthorn Group Peace River Fm. Arcadia Fm.
2	T = 205,000 gpd/ft S = 0.0003 (Based on the analysis of the IPW-2 response during the upper production zone APT)	Upper Floridan Aquifer	Upper Production Zone	Suwanee Limestone Ocala Limestone Avon Park Limestone/ Lake City Limestone
	K'/b' = 0.0032 day^{-1} (Based on the analysis of the IPW-2 response during the upper production zone APT)		Semi-Confining Layer	
3	T = 2,300,000 gpd/ft S = 0.00013 (Based on the analysis of the ICW-1 response during the lower production zone APT)	(?)	Lower Production Zone	

Notes

T = transmissivity

S = Storage Coefficient

S_y = Specific Yield

K'/b' = Leakage Coefficient

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Layer Scheme and Hydrogeologic Parameters Used in Impact Model

JOB NO.	FIGURE NO.	REV.
22019	15	0

some additional parameters needed to be obtained from other sources. These parameters included the transmissivity and storage coefficient of the Surficial aquifer, and the leakage coefficient between the Surficial aquifer and the Upper Production Zone of the Upper Floridan aquifer.

The Surficial aquifer has a transmissivity of 5,600 gpd/ft based on the results of an APT conducted in this aquifer at the site to obtain hydrogeologic information for input to the SCA (Indiantown Cogeneration, 1990). Geologic information collected as part of the site hydrogeologic investigation indicates that the Surficial aquifer is comprised predominantly of medium sand. Therefore, the storage coefficient of the Surficial aquifer was assumed to be 0.32 based on a representative value of specific yield for medium sand taken from Table 2-2 of McWhorter and Sunada (1977).

The leakage coefficient between the Surficial aquifer and the Upper Production Zone of the Upper Floridan aquifer was assumed to be 0.00001 day^{-1}. This is an intermediate value within a range of values presented on Figure 30 in Tibbals (1990). The leakage coefficients presented in Tibbals, which range between 0.00001 day^{-1} and 0.00005 day^{-1} in an area 20 to 30 miles north of the site, were estimated based on the results of a regional modeling analysis of the Floridan aquifer in east-central Florida.

Boundary and Initial Conditions

As stated earlier, the analysis considered two wells withdrawing water from the Upper Production Zone and four wells withdrawing water from the Lower Production Zone. Constant-flux boundaries were assigned to each of the finite-difference cells coinciding with one of the six wells.

All water was assumed to be removed from aquifer storage. Water in the Upper Floridan aquifer was assumed to be removed from elastic storage while water from the Surficial aquifer was assumed to be removed from the drainage of pores.

Because only drawdown, or the decline in water levels, caused by withdrawals at the Indiantown Cogeneration Plant is of concern, initial water levels in the model were uniformly set to zero.

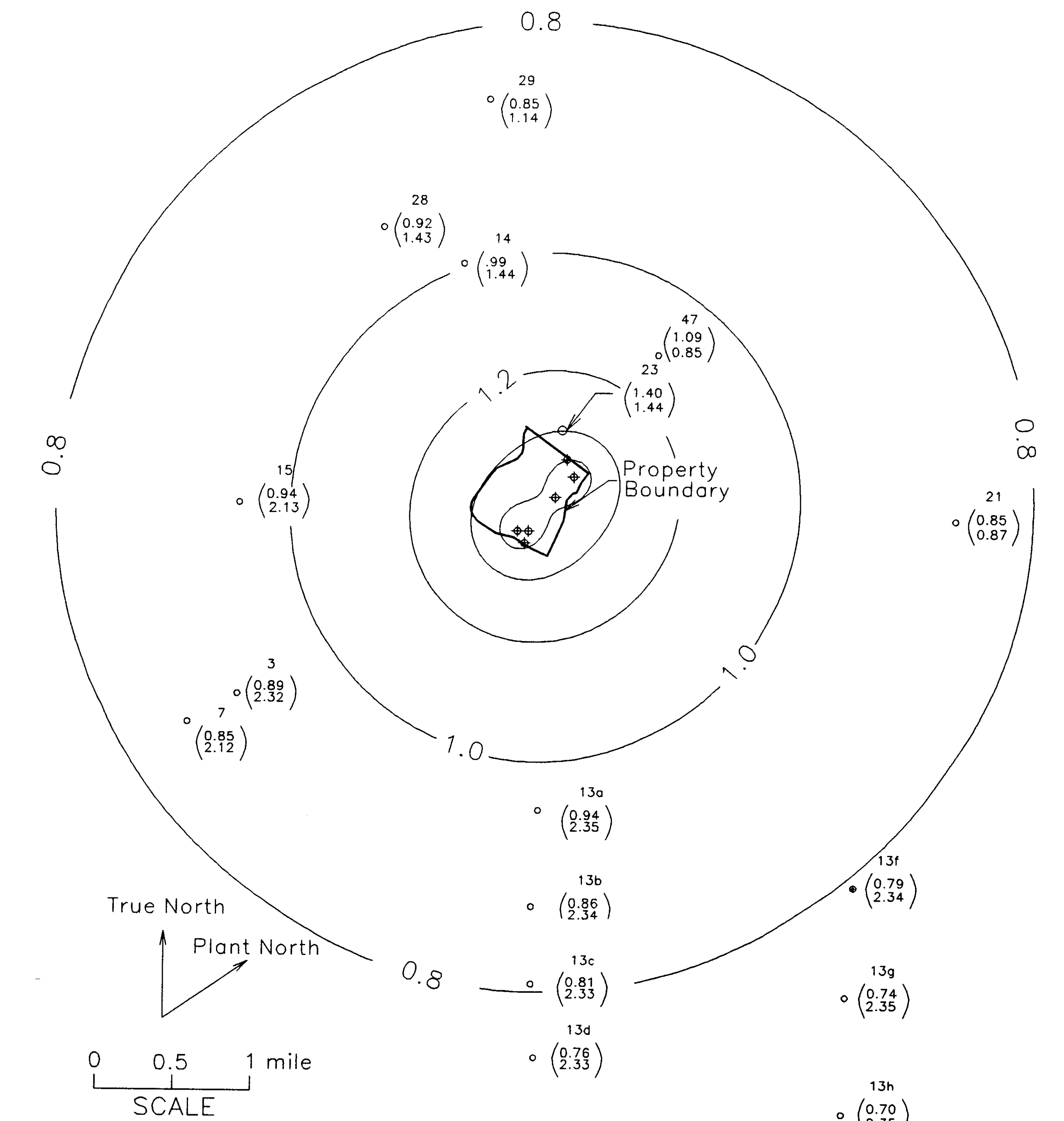
5.5 Impact Analysis Results

Drawdowns at individual wells in the vicinity of the Indiantown site, caused by plant withdrawals from the Upper and Lower Production Zones of the Upper Floridan aquifer, are shown on Figures 16 and 17 for the 75-day and 90-day pumping scenarios, respectively. The allowable drawdowns are also shown on the figures for comparison purposes. The output files generated by the MODFLOW computer model are provided in Appendix F.

Figures 16 and 17 show that the withdrawal capability is not reduced by more than 10 percent for all but one of the wells (#47). The one well that shows an impact corresponds to SFWMD permit number 43-00625, issued to VIA Tropical Fruits, Incorporated.

The calculated reduction in the withdrawal capability at well #47 exceeds the allowable amount largely because the height of the piezometric surface above the ground surface at the well is significantly reduced due to the location of the well at a higher elevation than most of the other wells in the area (well #47 is at an elevation of 40 feet whereas most of the other wells are between elevations of 25 and 30 feet). Because the height of the piezometric surface above the ground surface serves as the basis for determining whether a well has been adversely impacted, wells at higher elevations are more susceptible to adverse impacts than wells occurring at lower elevations.

As discussed in Section 5.3, the effects of friction loss in the surrounding permitted wells were ignored when calculating the drawdowns required to cause adverse impacts to the withdrawal capability of the wells. However, by ignoring the friction loss, the percent reduction in the withdrawal capability of the wells was in actuality, overestimated.



ICP Well Locations

13e (0.69 2.33) Well location (from Table 4–1) with computed drawdown (top number in parentheses) and allowable drawdown (bottom number in parentheses)

1.4 Computed drawdown in the upper production zone as a result of combined withdrawals of 3097 gpm from the lower production zone and 300 gpm from the upper production zone for a period of 75 days. Contour interval is 0.2 ft.

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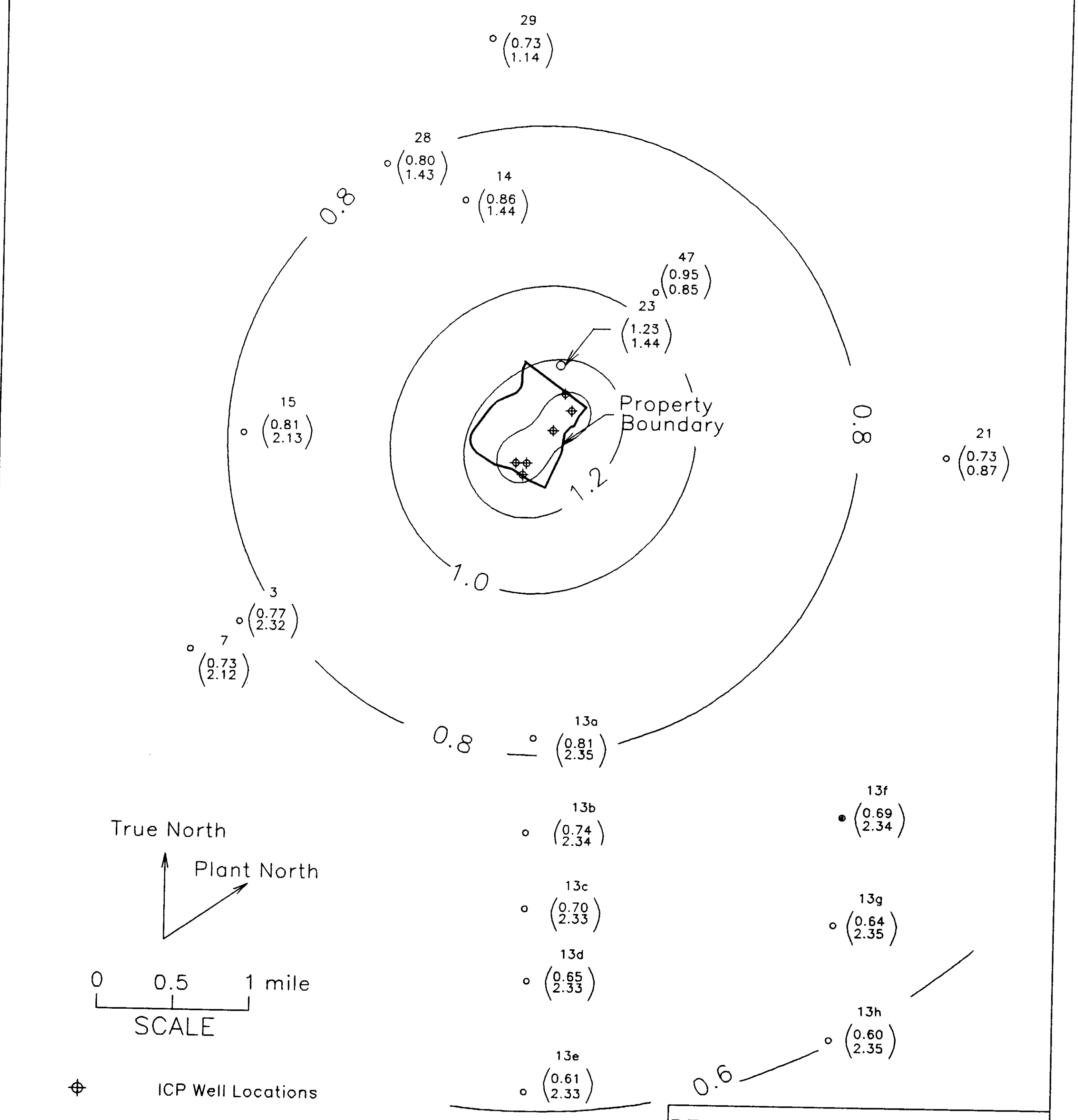
Drawdown in Upper Production Zone Resulting From 75 Days of Pumping at 3397 gpm

JOB NO.	FIGURE NO.	REV.
22019	16	0



ICP Well Locations

13e (0.69 2.33) — Well location (from Table 4–1) with computed drawdown (top number in parentheses) and allowable drawdown (bottom number in parentheses)

1.4 — Computed drawdown in the upper production zone as a result of combined withdrawals of 2597 gpm from the lower production zone and 300 gpm from the upper production zone for a period of 90 days. Contour interval is 0.2 ft.

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INDIANTOWN COGENERATION PROJECT INDIANTOWN, FLORIDA		
Drawdown in Upper Production Zone Resulting From 90 Days of Pumping at 2897 gpm		
JOB NO.	FIGURE NO.	REV.
22019	17	0

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