SUMMARY OF OFF-SITE DRILLING/TESTING NORTH OF AREA "A"
AT
NAVAL AIR WARFARE CENTER
WARMINSTER, PENNSYLVANIA

CONTRACT NO. N62472-94-D-0398
DELIVERY ORDER NO. J018

PREPARED FOR:

U.S. NAVY NORTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
10 INDUSTRIAL HIGHWAY
LESTER, PENNSYLVANIA 19113

FEBRUARY 23, 2000

Volume 1 of 2

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WP2000#/WP0009

NAVAL AIR WARFARE CENTER -WARMINSTER
SUMMARY OF OFF-SITE DRILLING/TESTING NORTH OF AREA "A"

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NAVAL AIR WARFARE CENTER – WARMINSTER
SUMMARY OF OFF-SITE DRILLING/TESTING NORTH OF AREA "A"

1.0 INTRODUCTION

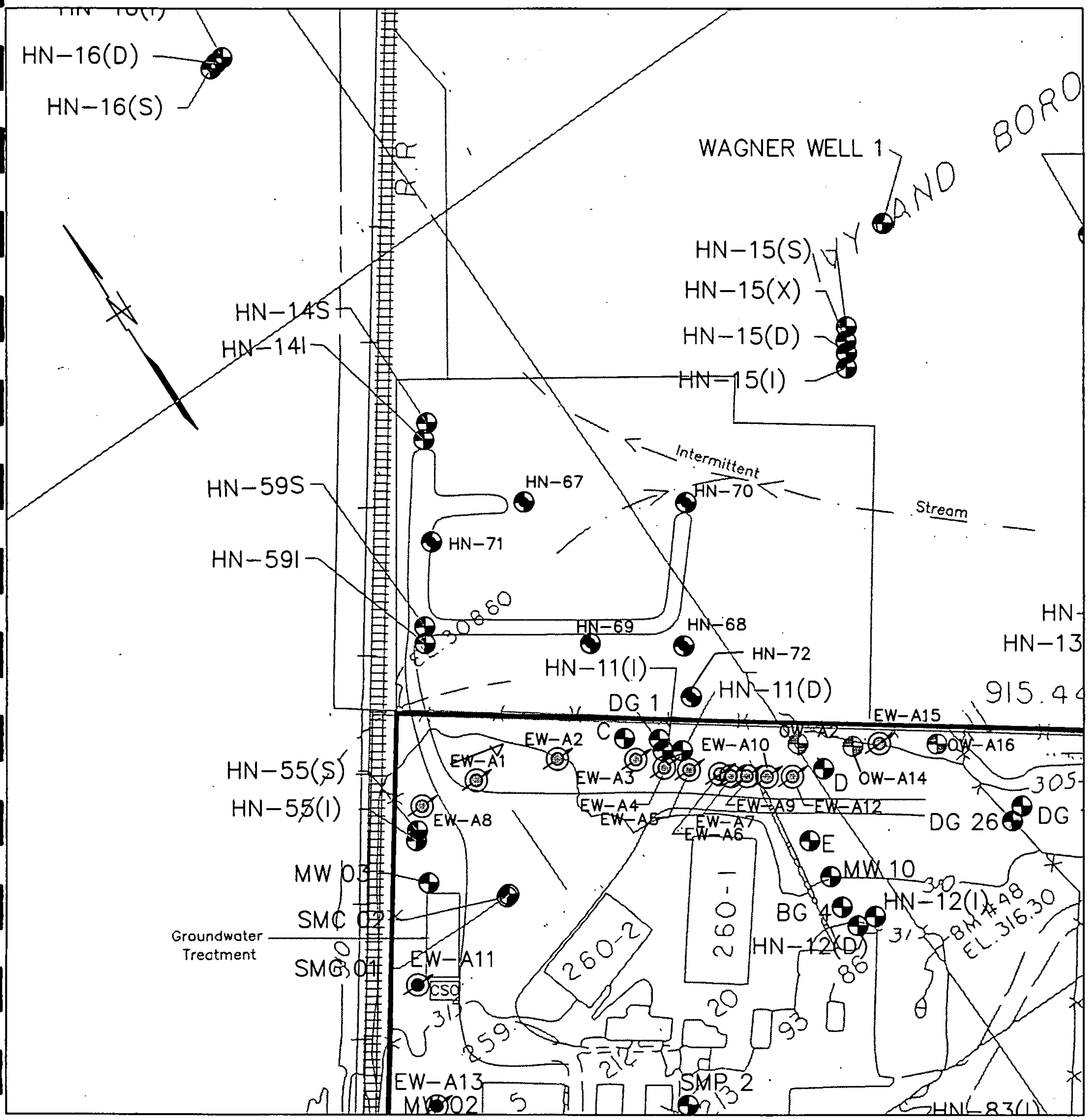
Foster Wheeler Environmental Corporation (Foster Wheeler Environmental) has been contracted by Northern Division, Naval Facilities Engineering Command to provide various remedial actions at the Naval Air Warfare Center, located in Warminster, Pennsylvania (NAWC-Warminster). This document has been prepared to satisfy requirements of Remedial Action Contract Number N62472-94-D-0398, Delivery Order No. J018 for various removal actions. This report specifically documents the procedures used to drill, test, and evaluate six off-site wells immediately north of Area A. One or more of these locations could potentially have been used to supplement the Area A groundwater extraction system. Results from short-term yield tests conducted at each off-site well are also detailed.

1.1 OVERVIEW OF FIELD ACTIVITIES

To assess the magnitude and extent of groundwater contamination immediately north of the Area A extraction well system, and to identify optimal locations for additional groundwater extraction wells, six (6) off-site wells were drilled and tested during December 1999 and January 2000 (Figure 1). The same drilling, testing, and decision processes used for the Area A extraction system was utilized for the off-site drilling program. These procedures were documented in Work Plan Addendum No.9, submitted to the Navy on November 24, 1999.

During the planning stages for this drilling program, the Technical Evaluation Group (TEG) had identified four initial drilling locations in the off-site area immediately north of Area A. Drilling was initiated at HN-68, located approximately 90 feet northeast of monitoring well HN-11I. The remaining six wells were drilled in the following sequence: HN-70 (12/12/99); HN-69 (12/15/99); HN-67 (12/20/99); HN-71 (1/5/2000); and, HN-72 (1/11/2000). After drilling to the desired total depth (T.D.), each open borehole was developed via air-lift pumping until discharged groundwater was relatively turbid free. After allowing the well(s) to stabilize overnight, a short-term (6-8 hour) yield test was conducted to assess hydraulic parameters and trichloroethene (TCE)/tetrachloroethene (PCE) concentrations in the shallow bedrock aquifer (Stockton Formation). The pumping rates were sufficient (ranging between 10-20 gallons/minute) to induce significant drawdown in the pumping well and nearby observation wells, so that aquifer parameters (transmissivity and storativity) could be estimated and the well locations could be assessed for suitability as extraction wells.

Air-hammer drilling techniques were used to install Area A wells to depths of between 80 to 107 feet below ground surface (bgs). Well depths were required not to penetrate a target mudstone unit (4^{th} mudstone at well HN-11I) in the Stockton Formation, which forms the base of the upper bedrock aquifer unit. Ten-inch diameter black steel surface casing was installed into competent bedrock (depth to competent bedrock ranged from approximately 10 to 22 feet bgs). Air, water, and cuttings from each well were monitored at 5-foot intervals via MicroFID flame ionization



0 150 300
SCALE IN FEET

Monitoring Wells

Extraction Wells

Newly-Installed

Note: Basemap Modified from Brown & Root Environmental,
Drawing No. 1412G103.dwg
Dated: 02/26/1998

U.S. Navy RAC
NAWC WARMINSTER – AREA A

Figure 1

WELL LOCATION MAP

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CADD FILE: warminster\pipeline\area a\newd.dwg detector (FID). Inflatable packer assemblies were used at several well locations to collect groundwater samples from isolated fractures. Groundwater produced during drilling operations was pumped to a large tanker truck before being transferred to, and processed in, the Area A groundwater treatment system.

1.2 DRILLING AND MONITORING PROGRAM

Air-hammer drilling techniques were used to advance the off-site boreholes. Using conventional air-hammer drilling, each extraction well was initially drilled utilizing a 14-inch diameter bit to a depth of approximately ten feet into competent bedrock (bedrock lies approximately 10 to 22 feet bgs). After 10-inch diameter surface casing was grouted in place, drilling proceeded to total depth using a nominal 10-inch diameter bit. The only exception to this was at HN-71, where 16-inch surface casing was installed to 22 feet bgs. Borehole logs for each location are provided in Appendix A.

The drilling subcontractor used vegetable oil-based lubricants on drill pipe joints. The drilling subcontractor containerized all drill cuttings in a specified roll-off dumpster located adjacent to each drilling location. The Foster Wheeler Environmental Project Hydrogeologist and Health and Safety Officer monitored cuttings continuously for lithologic variation, and for the presence of volatile organic compounds (VOCs) and/or dense non-aqueous phase liquid (DNAPL). Groundwater produced during drilling operations was pumped into a large frac tank, before being transferred to the Area A groundwater treatment system for processing/disposal.

An FID was used to continuously monitor air, water, and drill cuttings discharged from the borehole during drilling. The FID readings and times were recorded for every five feet of drilling penetration. The FID was calibrated daily, in accordance with the manufacturer's specifications. Calibration records are maintained in the site files. Field screening for DNAPL using Oil-Red-O dye was performed on groundwater samples from boreholes with FID readings above 20 parts per million (ppm).

While drilling in the off-site area, groundwater samples were collected on a daily basis from HN-14S/I and HN-59S/I. Samples from these wells were obtained via submersible pumps in accordance with low "stress" (modified low-flow) groundwater sampling procedures. Groundwater samples were preserved in 40 ml VOA vials, and were analyzed in the field for TCE/PCE content using a PhotoVac 10S70 gas chromatograph (GC). In addition, water levels were measured every two hours at all monitoring well located within 200 feet of an active drilling location. As new offsite borings were completed, a daily groundwater sample was collected from each open hole boring during drilling activities.

The groundwater samples were field analyzed (via GC) on the same day they were obtained. Samples collected from each newly-installed boring at the end of each yield test were field analyzed via GC, and sent to a fixed laboratory for confirmatory analyses. Cumulative sample results are discussed in Section 4. Copies of laboratory data and chains-of custody are provided in Appendix B.

1.3 YIELD TESTS

The Area A extraction well network was originally designed to intercept and prevent contaminated groundwater from migrating downgradient (north-northwest) and off-site. Well spacing was chosen (based on yield tests) to ensure a continuous capture zone was created and sustained by the extraction well network. Yield tests were also conducted at each off-site boring location to evaluate the hydraulic characteristics in the fractured bedrock aquifer, to further evaluate the TCE/PCE concentrations at each location, and to assess the potential yield and capture zone that could be produced by each well.

1.3.1 Yield Test Setup and Monitoring

To pump each well, a submersible pump capable of delivering approximately 20 gpm at 200 psi was positioned approximately five (5) feet above the bottom of the borehole. Discharge fittings were secure and leak proof. Test pump discharge piping included, in order of placement from the pump site: a flow adjustment valve; a flow meter (turbine type with totalizer); and, a sample port. To ensure measuring accuracy, the discharge pipe included an appropriate length of straight, blank pipe before and after the metering devices. Discharge piping was routed to a large frac tank, where the extracted water was held before transferring to the Area A groundwater treatment system.

An FID was used to monitor the discharge water quality during each yield test. Samples were placed in a wide-mouth jar and covered with foil. After waiting approximately one minute, the foil was pierced with the FID sample tube, and the VOCs in the headspace were measured. The FID was properly calibrated prior to each test, with the calibration and monitoring results recorded in the field logbook. Field GC analyses were also performed on discharge samples collected every hour during each yield test. A confirmatory sample, collected at the end of each yield test, was submitted to a fixed laboratory.

1.3.2 Water Level Measurement Equipment

Water levels in existing monitoring wells (observation wells) were measured with an electronic monitoring device at each well relative to a clearly marked point at the top of the inner casing. Water levels in the newly-installed open boreholes were measured relative to the top of surface casing.

Automatic water level data loggers using pressure transducers (TELOG 2109 series) were used to monitor/record water levels in the pumping well and four nearby wells located within 300 feet of the pumping well. Each transducer was secured to the surface well casing to prevent movement during the test.

All field personnel involved in the pump tests used synchronized watches, enabling data recording to the nearest second. Water level measurements collected manually were recorded for each individual observation well on "Pump Test Data Forms".

1.3.3 Pre-Test Measurements

Discharge rate was controlled by valving. Equipment/pump testing was conducted the day before each yield test, with pumping time approximately five minutes. Testing parameters were recorded in the field logbook.

Static water levels were measured by hand (using electronic water level indicators) in all wells located within 300 feet of the pumping well. Any significant variations in water levels were noted, and if appropriate, investigated (i.e., barometric effects, nearby pumping, surface discharges, etc.).

The automated data loggers (TELOG 2109) were installed in four nearby observation wells and the pumping well, with recorders programmed to record data at 30-second intervals. Depth to water (DTW) via hand measurements and data logger readouts were recorded for comparison.

1.3.4 Starting a Yield Test

Manpower for each yield test included three Foster Wheeler Environmental personnel (a geologist/health and safety officer and two other environmental staff), and one or more operators from the drilling subcontractor to operate the pump and maintain the generator. When the pump operators started the pump, personnel hand gauged the pumping and the observation wells, and monitored the discharge flow rate. The discharge flow rate was monitored approximately every five minutes for the first 30 minutes of the pump test, at ten minute intervals for the first hour, and at least once/hour for the remainder of the pump test. Flow rates were adjusted, as needed, to maintain a constant rate (15-20 GPM, if possible). All measurements, adjustments, and times were recorded in the field logbook/pump test forms.

Water levels in the pumping well were hand-measured approximately at 30-second intervals for five minutes; one minute intervals from 5-10 minutes; two minute intervals from 10 to 30 minutes; every five minutes from 30 to 60 minutes; and, at 30 minute intervals for the remainder of the test. Water levels in the observation wells hand-measured approximately every 30 minutes during the first hour of the test, and hourly thereafter.

1.3.5 Water Quality Testing

The discharge water quality was field tested once every hour, using a portable PhotoVac 10S70 GC.

Discharge samples were collected for laboratory analyses (Section 4) immediately prior to terminating the yield test. Laboratory samples were collected from the discharge sampling port, and placed into two labeled and preserved (HCl) 40 ml VOA vials. The sample vials were placed in an iced cooler and shipped to the laboratory for analyses via EPA Method 601. Forty-eight (48) hour turnaround time was performed for laboratory results.

1.3.6 Yield Test Recovery Data

At the conclusion of each pumping test, water level recovery data were obtained when the pump was shut off (to measure rising head). Recovery data at the pumping well, and the four nearby observation wells with automated recorders, were recorded for a minimum of one hour. Levels were also hand-measured, using the frequency intervals specified for the start of the test.

1.3.7 Yield Test Data Analysis

Semi-logarithmic plots of time versus drawdown and distance versus drawdown were prepared for the pumping well and observation wells. Data for graph preparation include both hand-measured water level data and depth-converted data logger readings.

The Cooper-Jacob (1946) straight-line method was used to determine transmissivity (T) and storage coefficient (S) using the distance-drawdown, time-drawdown, and recovery data. Greatest emphasis is given to the determination of T using distance-drawdown data, since this data provides averages over the greatest area of the aquifer, and can best account for axial variations.

The relevant equations for the Cooper-Jacob method using time-drawdown, residual drawdown (T only), and calculated recovery data are as follows:

$$T = \frac{264Q}{\Delta s}$$

$$S = \frac{0.3\,Tt_0}{r^2}$$

where, T = Transmissivity (gpd/ft)
Q = pumping rate (gpm)
Δs = change in drawdown over one log cycle (feet)

S = Storage Coefficient (dimensionless)
T = Transmissivity (gpd/ft)
t_0 = intercept of straight line at zero drawdown (days)
r = distance (feet) from the pumped well to the observation well

The relevant equations for the Cooper-Jacob Method using distance-drawdown data are as follows:

$$T = \frac{528Q}{\Delta s}$$

$$S = \frac{0.3\,Tt}{r_0^2}$$

where, T = Transmissivity (gpd/ft)
Q = pumping rate (gpm)
Δs = change in drawdown over one log cycle (feet)

S = Storage Coefficient (dimensionless)
T = Transmissivity (gpd/ft)
t = time since pumping started (days)
r_0 = intercept of extended straight line at zero drawdown (feet)

All aquifer test methods specified above are described in detail in Groundwater and Wells (Driscoll, 1986) and Analysis and Evaluation of Pumping Test Data (Kruseman and deRidder, 1990).

Water quality results from the field GC and fixed laboratory analyses were reviewed to evaluate the magnitude and extent of TCE/PCE contamination in off-site groundwater, with the objective of identifying which off-site boreholes should be converted to extraction wells to supplement the Area A groundwater remediation system. Capture zones for each well were evaluated using a combination of the Javandel and Tsang Method (as described in the Work Plan Addendum), and by adding the well characteristics and pumping rates to an existing QuickFlow 2D analytical groundwater flow model developed for the Area A extraction well system.

1.3.8 Yield Test Decisions

The yield test analyses, water quality data, and recommended locations for additional boring locations, were reviewed and discussed by the TEG the day after each test. Conference calls were held to discuss the results, and to determine if a given well location was suitable for completion as an additional Area A extraction well.

2.0 YIELD TEST RESULTS

Yield test data for the off-site wells is summarized in Table 1. Drawdown/Recovery graphs and field data sheets for each test are included in Appendix C. Wherever possible, estimates of transmissivity (T) and storage coefficient (S) were made from time-drawdown, distance-drawdown, and recovery plots for the pumping well(s) and nearby observation wells. Irregularities in drawdown data from some of the pumping wells precluded estimating T and S from those wells. Estimates of T and S derived from distance-drawdown plots, and recovery data from nearby observation wells are considered to be the most reliable data. Hydraulic calculations from distance-drawdown data represent aquifer conditions over a wider area than single-well estimates. Recovery data should be a mirror-image of pumping drawdown, but can be more reliable because water levels recover at a constant rate, whereas it is often difficult to maintain a constant pumping rate during a test. Use of recovery data is considered more reliable in pumping wells because there is no in-well turbulence during recovery.

All yield tests were conducted in open, unscreened boreholes. None of the newly installed off-site boreholes had been completed with screen and riser at the time of the yield tests. Existing, nearby monitoring wells used as observation wells were all completed with 2-inch diameter PVC screen and riser, and generally contained a 10-20 foot section of screen within the shallow bedrock aquifer (partially-penetrating wells).

The geometric mean T value based on time-drawdown and recovery data range from 324 sq.ft/day at HN-68 to 488 sq.ft/day at HN-71. The geometric mean T value based on distance-drawdown analyses for the six wells is 462 sq.ft/day. These values are similar to estimates derived from the Area A extraction wells that had sustained yields exceeding five (5) GPM.

TABLE 1
NAWC - WARMINSTER, PA
Summary of Short-term Yield Tests Conducted at Off-site Well, Area "A"

Pumping Well & *Rate*	Analysis/ Observation Well(s)	Distance in Feet from Pumping Well	Transmissivity		Storage Coefficient
			gpd/ft	sq.ft./day	
HN-67	Time-Drawdown at HN-67	NA	3,300	441	NA
20 GPM	Distance-Drawdown [(1)]				
HN-68	Residual Drawdown, HN-68	NA	2,456	328	NA
20 GPM	Distance-Drawdown	3350[(2)]	3,580	478	2.40E-05
	Time-Drawdown, HN-11I	90	2,031	272	3.40E-04
	Calc-Recovery, HN-11I	90	2,200	294	2.30E-04
	Residual Drawdown, HN-11I	90	2,200	294	NA
	Time-Drawdown, HN-59S	168	2,031	272	2.10E-04
	Calc-Recovery, HN-59S	168	2,983	399	1.10E-04
	Residual Drawdown, HN-59S	168	3,406	455	NA
HN-69	Residual Drawdown, HN-69	NA	2,795	374	NA
~ 18 GPM	Distance-Drawdown	3000[(2)]	4,874	652	4.00E-05
	Time-Drawdown, HN-70	188	3,066	410	1.80E-04
	Calc-Recovery, HN-70	188	4,320	578	6.40E-05
	Residual Drawdown, HN-70	188	4,320	578	NA
	Time-Drawdown, HN-68	98	2,715	363	4.00E-04
	Calc-Recovery, HN-68	98	3,394	454	1.50E-04
	Residual Drawdown, HN-68	98	3,394	454	NA
HN-70	Distance-Drawdown	890[(2)]	1,929	258	1.80E-04
19 GPM	Time-Drawdown, HN-68	152	1,824	244	2.10E-04
	Calc-Recovery, HN-68	152	3,215	430	6.40E-05
	Residual Drawdown, HN-68	152	3,583	479	NA
	Time-Drawdown, HN-59S	248	1,929	258	1.10E-04
	Calc-Recovery, HN-59S	248	3,175	424	5.00E-05
	Residual Drawdown, HN-59S	248	3,858	516	NA
	Time-Drawdown, HN-11I	228	1,929	258	1.50E-04
	Calc-Recovery, HN-11I	228	2,951	394	1.20E-04
	Residual Drawdown, HN-11I	228	2,787	373	NA
	Time-Drawdown, HN-14I	240	1,915	256	2.70E-04
	Calc-Recovery, HN-14I	240	2,711	363	1.20E-04
	Residual Drawdown, HN-14I	240	3,236	433	NA
HN-71	Time-Drawdown, HN-71	NA	3,344	447	NA
19 GPM	Distance-Drawdown	1600[(2)]	4,894	654	1.40E-04
	Time-Drawdown, HN-14I	97.5	3,344	447	2.70E-04
	Calc-Recovery, HN-14I	97.5	2,711	363	2.20E-04
	Residual Drawdown, HN-14I	97.5	2,711	363	NA
	Time-Drawdown, HN-68	275	4,180	559	1.20E-04
	Calc-Recovery, HN-68	275	4,870	651	8.00E-05
	Residual Drawdown, HN-68	275	5,118	684	NA
HN-72	Distance-Drawdown	560[(2)]	2,984	399	7.10E-04
~13 GPM	Time-Drawdown, HN-68	39	3,269	437	7.60E-04
	Calc-Recovery, HN-68	39	1,716	229	1.20E-03
	Residual Drawdown, HN-68	39	1,716	229	NA
	Time-Drawdown, HN-59S	265	4,038	540	1.20E-04
	Calc-Recovery, HN-59S	265	2,933	392	1.10E-04
	Residual Drawdown, HN-59S	265	2,860	382	NA

Notes: 1) Initial pump test conducted on Dec. 21, 1999 indicated well had not been drilled deep enough. Well was not retested after drilling deeper to total depth of 102 feet bgs.
2) Radius of Influence (ROI) determined from Distance-Drawdown plot

Transmissivity values for low yielding (less than 5 GPM) wells at Area A (such as EW-A4, EW-A5, EW-A6, EW-A7, and EW-A9) were on the order of 150-250 sq.ft/day. Storage coefficients are generally in the 10^{-4} range, which is typical for a confined or semi-confined aquifer.

3.0 DRAWDOWN MEASURED DURING PUMPING TESTS

Depth to water ranged from approximately 15-20 feet below top of casing (TOC) in all off-site boreholes, resulting in a total available drawdown of between 55-80 feet for these wells. While pumping/testing these boreholes at rates of between 13-20 GPM, only HN-72 exhibited drawdown exceeding 30% total available drawdown. HN-72 was the lowest yielding off-site borehole, and also exhibited the highest VOC readings (discussed below in Section 4). This well is located closest to the low-yielding, "hot" wells (EW-A6, EW-A7) in the Area A extraction well network.

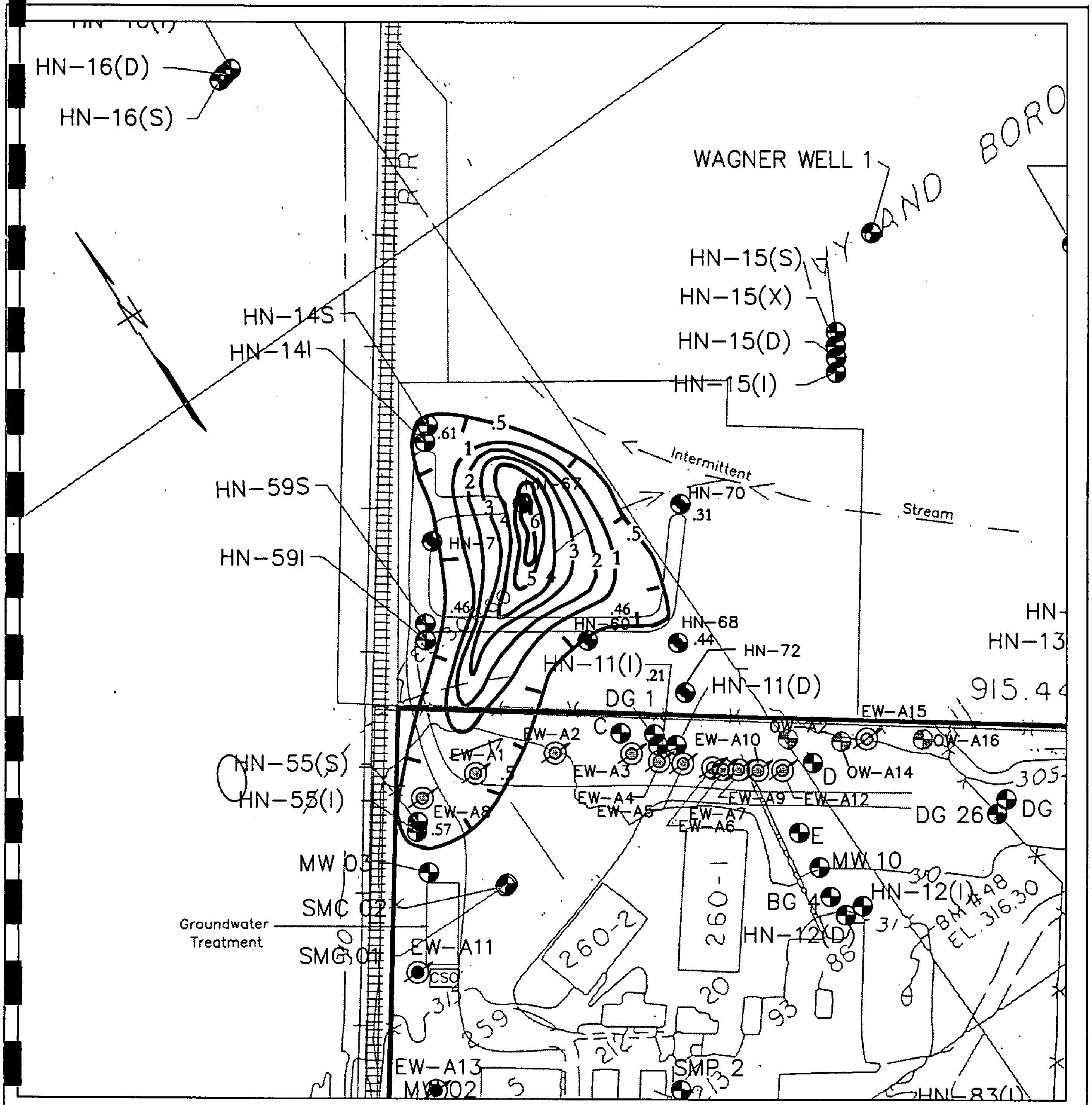
Drawdown values measured by hand for the pumping and observation wells are presented in Appendix C. Drawdown plots from pumping wells and select observation wells used for hydraulic analysis and interpretation, were presented and discussed in Section 2.

Figures 2 through 7 illustrate the maximum drawdown observed in observation wells at the end of each yield test. These plots indicate that each well produces significant drawdown in observation wells tens of feet away. The radius of influence (ROI) appears to be several hundred feet for most wells. With the exception of HN-71, the drawdown pattern (cone of depression) generally tends to be somewhat elongated in a west-southwest to east-northeast direction. A similar (fracture-controlled) orientation was often noted at Area D. The overall drawdown pattern at HN-71 was circular, with a strong north-south component running between HN-71 and HN-11I.

4.0 WATER QUALITY DATA

Tables 2 through 9 summarize the water quality data collected during drilling/testing of the off-site well locations. The majority of the data consists of field GC screening, while a subset of samples were submitted for confirmatory laboratory analyses. Figures 8 and 9 illustrate the correlation between field GC and confirmatory lab results. In general, samples exhibiting ppm-level concentrations showed an excellent correlation (R^2 of .96). Samples with concentrations ranging between 200-300 ppb, did not correlate as well (R^2 of .52 for linear regression and .61 using a 3rd-order polynomial).

While drilling each borehole, groundwater samples were collected via low-stress sampling protocol from monitoring wells HN-14S/I and HN-59S/I. These samples were analyzed for TCE/PCE via field GC to monitor the possibility of downgradient migration of any free-product (DNAPL) caused by drilling in the fractured bedrock. The only contaminant variations noted during the sampling program were believed to be due to intermittent shutdown of the Area A extraction well system. The Area A extraction well system was shutdown twice (for



0 150 300

SCALE IN FEET

Monitoring Wells

Extraction Wells

Newly-Installed

.57 Drawdown (Feet)

Note: Basemap Modified from Brown & Root Environmental,
Drawing No. 1412G103.dwg
Dated: 02/26/1998

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NAWC WARMINSTER – AREA A

Figure 2

Drawdown During Field Test at HN-67 (20 GPM)
Prior to Deepening Well to 102' (From 75')
Dec. 21, 1999

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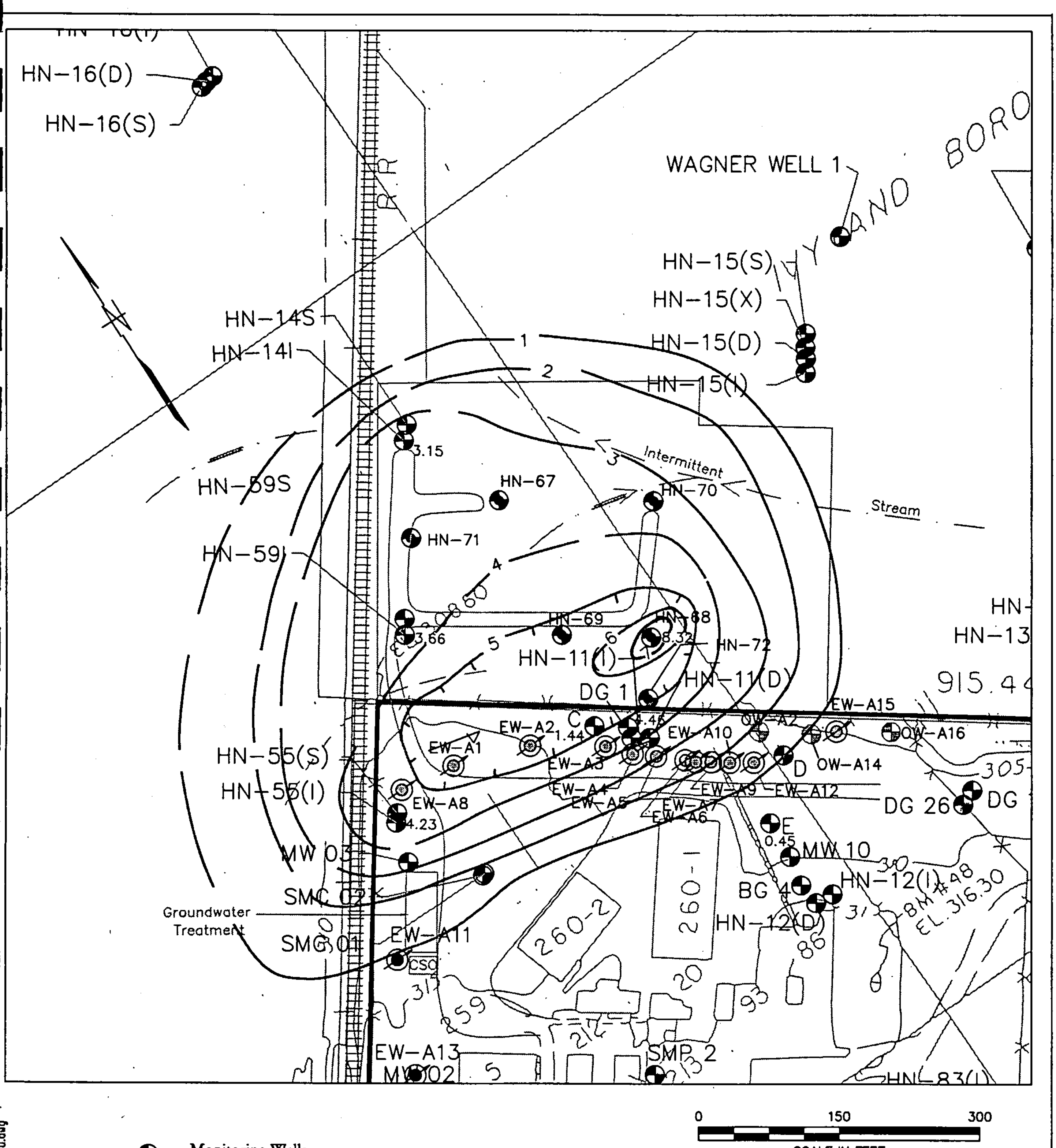

Monitoring Wells

Extraction Wells

Newly-Installed

3.66 Drawdown (Feet)

Note: Basemap Modified from Brown & Root Environmental, Drawing No. 1412G103.dwg Dated: 02/26/1998

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NAWC WARMINSTER – AREA A

Figure 3
Drawdown During Field Test at HN-68 (20 GPM)
Dec. 8, 1999

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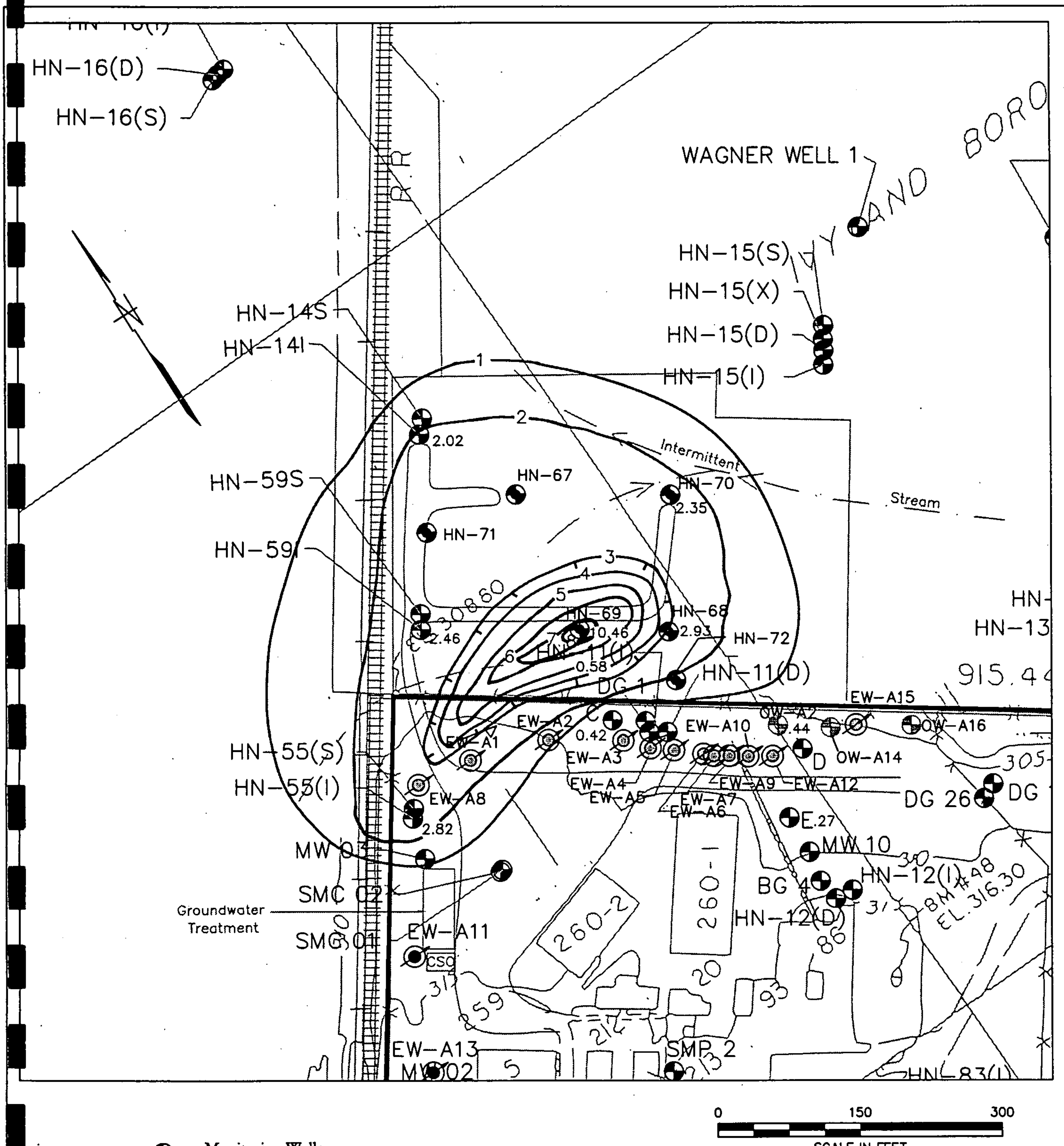
CADD FILE: warminster\pipeline\area-a\newd.dwg



Monitoring Wells

Extraction Wells

Newly-Installed

2.93 Drawdown (Feet)

Note: Basemap Modified from Brown & Root Environmental,
Drawing No. 1412G103.dwg
Dated: 02/26/1998

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NAWC WARMINSTER – AREA A

Figure 4
Drawdown During Field Test of HN-69
(18 GPM)
Dec 16, 1999

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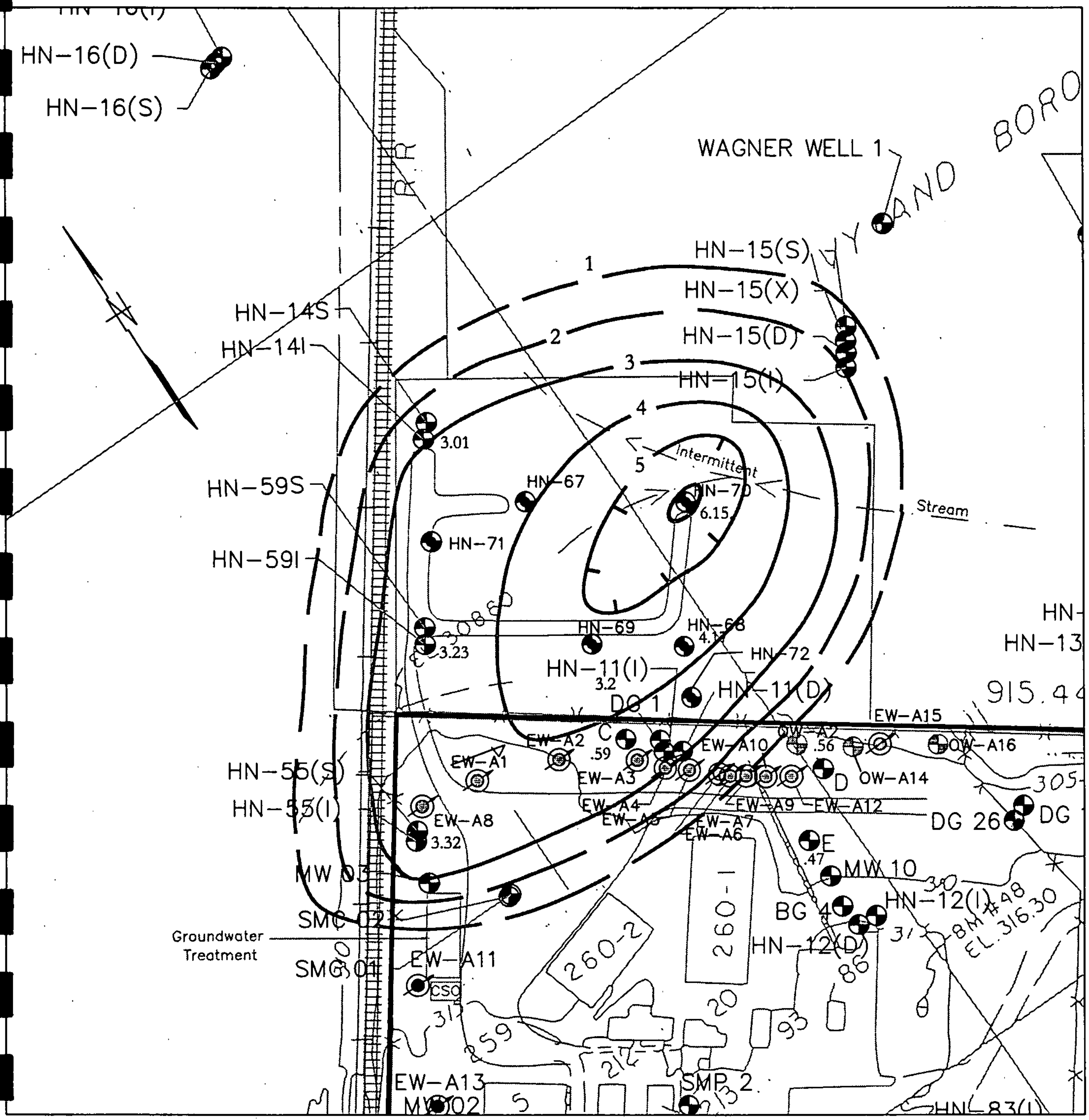

◐	Monitoring Wells
◎	Extraction Wells
●	Newly-Installed
3.23	Drawdown (Feet)

0 150 300
SCALE IN FEET

Note: Basemap Modified from Brown & Root Environmental, Drawing No. 1412G103.dwg
Dated: 02/26/1998

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NAWC WARMINSTER – AREA A

Figure 5
Drawdown During Field Test at HN-70
(19 GPM)
Dec 13, 1999

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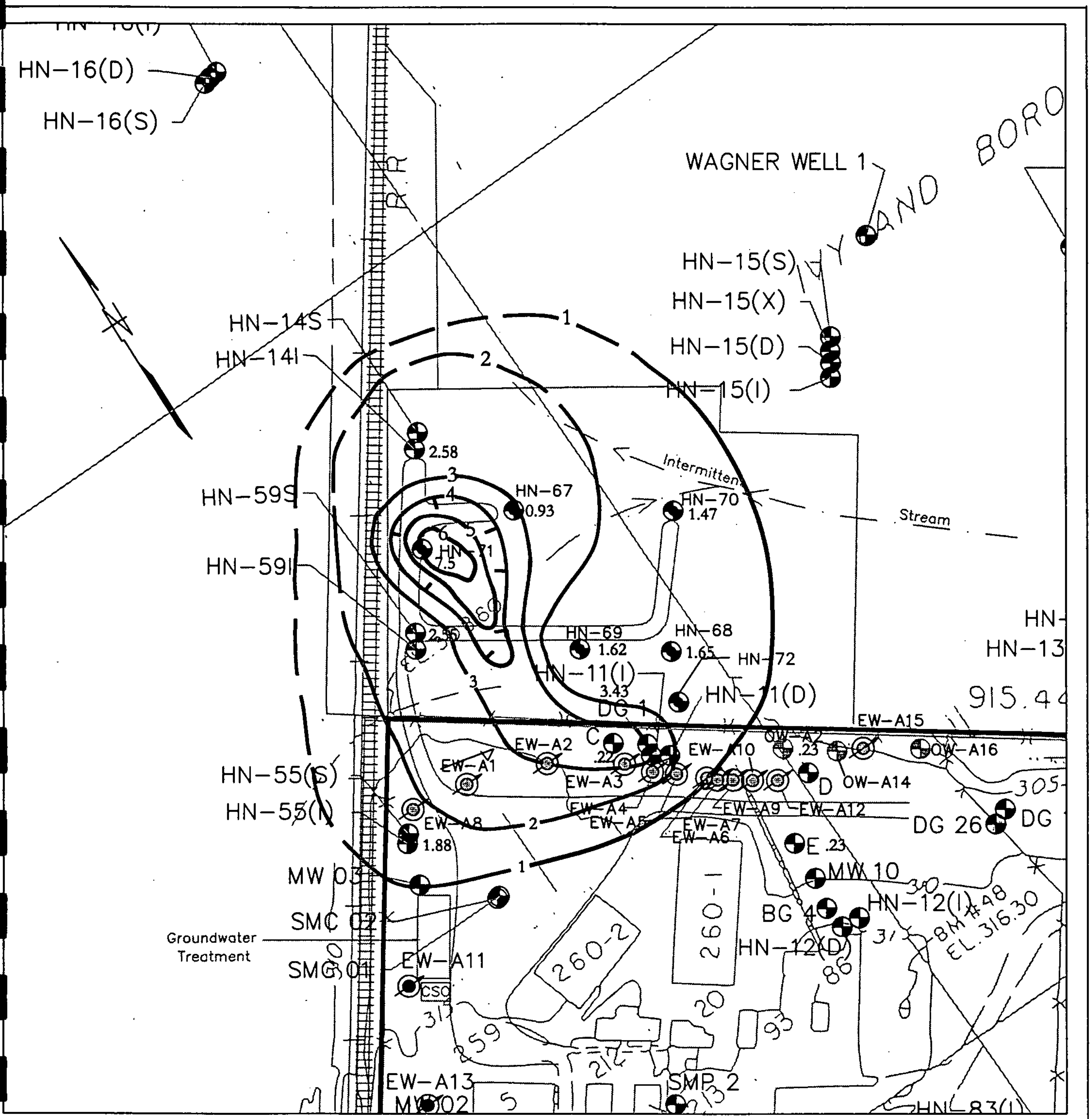

0 150 300

SCALE IN FEET

- Monitoring Wells
- Extraction Wells
- Newly-Installed
- 1.62 Drawdown (Feet)

Note: Basemap Modified from Brown & Root Environmental, Drawing No. 1412G103.dwg
Dated: 02/26/1998

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NAWC WARMINSTER – AREA A

Figure 6
Drawdown During Field Test at HN-71
(19 GPM)
Jan 6, 2000

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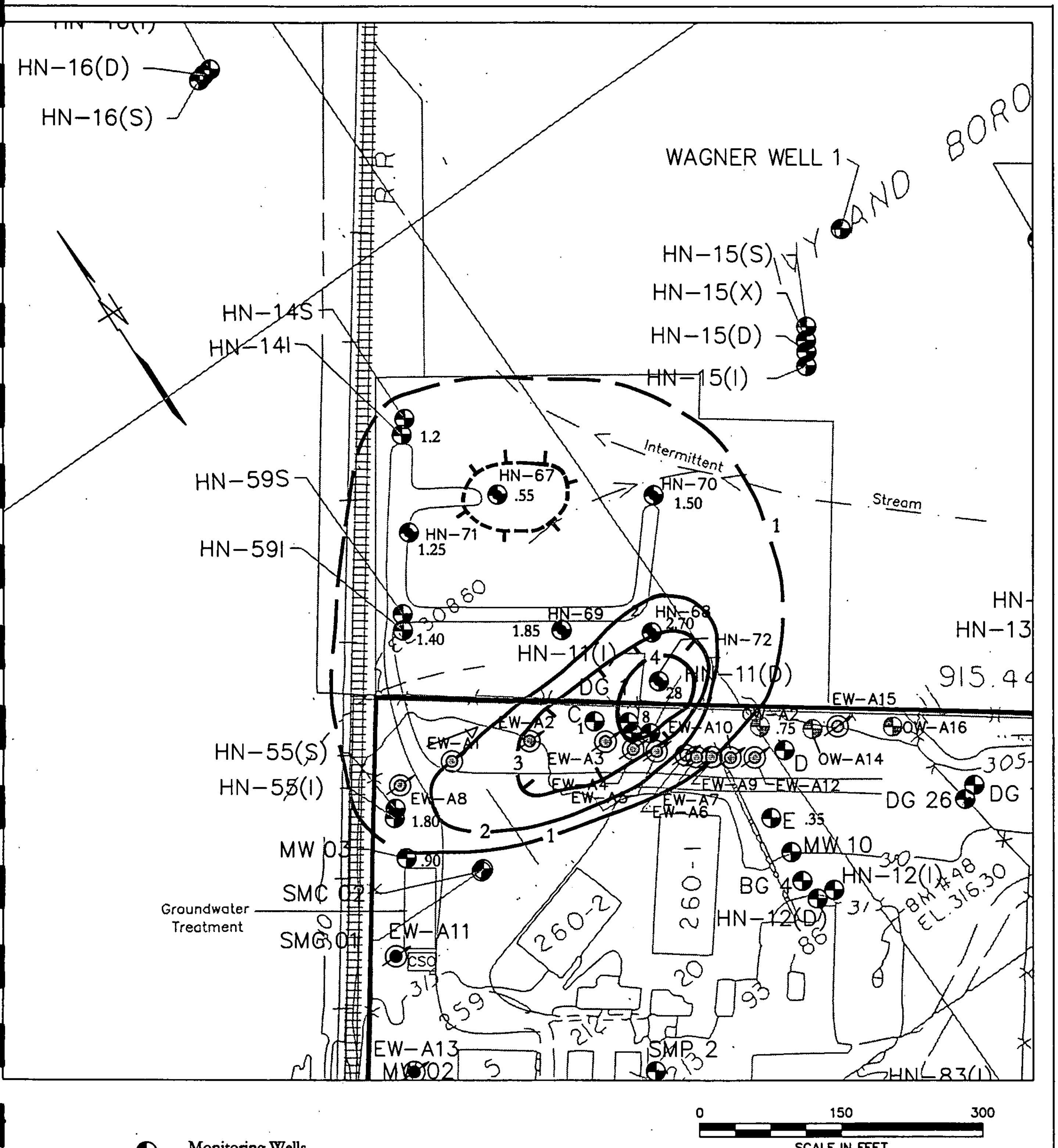

Monitoring Wells

Extraction Wells

Newly-Installed

2.70 Drawdown (Feet)

Note: Basemap Modified from Brown & Root Environmental,
Drawing No. 1412G103.dwg
Dated: 02/26/1998

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NAWC WARMINSTER - AREA A

Figure 7
Drawdown During Field Test at HN-72
(13 GPM)
Jan 12, 2000

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TABLE 2
NAWC - Warminster, PA
Analytical Results for HN-67

SAMPLE DATE	SAMPLE TIME	TCE, ppb	PCE, ppb
Yield Test Data			
12/20/1999	0935	33	20
12/20/1999	1030	41	18
12/20/1999	1130	49	17
12/20/1999	1230	42	9
12/20/1999	1330	49	17
12/20/1999	1430	58	4
12/20/1999	1455	66	6
Lab result - 12/20/99	1455	87	NA
Routine monitoring			
12/27/1999	1530	100	NA
1/7/2000	1010	103	ND
1/11/2000	1146*	72	ND
1/13/2000	1403	38	ND
1/21/2000	1052	168	ND
1/27/2000	1220	248	ND
HN-67 Packer Sample below 80'			
12/22/1999	1330	430	2

NA - Not Analyzed
ND - Not Detected

** Turbidity did not stabilize during purging*

TABLE 3
NAWC - Warminster, PA
Analytical Results for HN-68

SAMPLE DATE	SAMPLE TIME	TCE, ppb	PCE, ppb
Yield Test Data			
12/8/1999	1232	5,800	220
12/8/1999	1432	7,400	ND
Lab Result - 12/8/99	1430	6,100	29
Routine Monitoring			
12/9/1999	1437	7,100	51
12/15/1999	*No sampling due to well inaccessibility.*		
12/17/1999	1420	2,020	54
12/22/1999	1554	1,550	14
12/28/1999	1520	3,800	NA
12/30/1999	1043	4,210	NA
1/4/2000	1402	3,850	NA
1/5/2000	1113	3,340	NA
Lab Result - 1/6/00	1415	2,600	24
Lab Result - 1/7/2000	1415	3,450	60
1/11/2000	0916	1,760	11
1/13/2000	1558	1,070	ND
1/21/2000	1454	2,400	12
1/27/2000	0950	1,960	ND

NA - Not Analyzed
ND - Not Detected

TABLE 4
NAWC - Warminster, PA
Analytical Results for HN-69

SAMPLE DATE	SAMPLE TIME	TCE, ppb	PCE, ppb
Yield Test Data			
12/16/1999	0845	190	4
12/16/1999	1000	260	4
12/16/1999	1100	250	5
12/16/1999	1150	250	9
12/16/1999	1245	290	8
12/16/1999	1350	300	4
12/16/1999	1405	280	3
Lab result 12/16/99	1405	650	<25
Routine Monitoring			
12/17/1999	1547	160	ND
12/22/1999	1625	94	ND
12/28/1999	1431	145	NA
12/30/1999	1001	220	NA
1/4/2000	1322	120	NA
1/5/2000	1029	120	NA
1/11/2000	0948	134	ND
1/13/2000	1505	70	ND
1/21/2000	1326	1,400	ND
1/27/2000	1025	230	ND
Packer Sample Below 79'			
12/27/1999	1622	94	NA
Lab result 12/27/99	1622	100	2

NA - Not Analyzed
ND - Not Detected

TABLE 5
NAWC- Warminster, PA
Analytical Results for HN-70

SAMPLE DATE	SAMPLE TIME	TCE, ppb	PCE, ppb
Yield Test Data			
12/13/1999	1030	520	ND
12/13/1999	1130	220	ND
12/13/1999	1230	260	ND
12/13/1999	1330	270	ND
12/13/1999	1430	240	ND
12/13/1999	1530	200	ND
Lab Result 12/13/99	1525	310	15
Routine Monitoring			
12/15/1999	No sampling due to well inaccessiblity.		
12/17/1999	1509	250	28
12/22/1999	1507	110	8
12/28/1999	1610	145	NA
12/30/1999	1133	60	NA
1/4/2000	1446	150	NA
1/5/2000	1149	130	NA
1/11/2000	0821	180	10
1/13/2000	1535	164	NA
1/21/2000	1518	140	ND
1/27/2000	1425	375	ND

NA - Not Analyzed
ND - Not Detected

TABLE 6
NAWC - Warminster, PA
Analytical Results for HN-71

SAMPLE DATE	SAMPLE TIME	TCE, ppb	PCE, ppb
Sample before drilling below 75ft			
1/4/2000	1210	230	NA
Lab result 1/4/00	1210	110	ND
Packer Sample below 80 ft			
1/5/2000	1500	250	NA
Lab Result - 1/5/00	1500	770	14
Yield Test Data			
1/6/2000	1000	150	NA
1/6/2000	1100	190	NA
1/6/2000	1200	180	NA
1/6/2000	1300	200	NA
1/6/2000	1400	220	NA
1/6/2000	1500	210	NA
1/6/2000	1525	210	NA
Lab Result - 1/6/00	1525	510	10
Routine Monitoring			
1/7/2000	1055	76	ND
1/11/2000	1439	66	ND
1/13/2000	1438	90	ND
1/21/2000	1025	330	46
Lab Result - 2/4/2000	1040	53	13

NA - Not Analyzed
ND - Not Detected
No HCl in VOA vials on 2/4/2000. Samples analyzed on 2/8/2000

TABLE 7
NAWC - Warminster, PA
Analytical Results for HN-72

SAMPLE DATE	SAMPLE TIME	TCE, ppb	PCE, ppb
Yield Test Data			
1/12/2000	0950	8,700	16
1/12/2000	1040	8,900	D
1/12/2000	1140	9,600	D
1/12/2000	1240	6,900	D
1/12/2000	1340	6,800	D
1/12/2000	1440	7,500	D
1/12/2000	1540	7,900	D
Lab Result -1/12/00	1505	9,000	29
Routine Monitoring			
1/21/2000	1428	10,700	D
1/26/2000	1302	24,000	160
Lab Result - 2/4/2000	1210	6,100	220

NA - Not Analyzed
ND - Not Detected
D - Sample analyzed at a dilution. PCE may be diluted out.
No HCl in VOA vials on 2/4/2000. Samples analyzed on 2/8/2000

TABLE 8
NAWC - Warminster, PA
Analytical Results for HN-14S/I

HN-14S

SAMPLE DATE	SAMPLE TIME	TCE, ppb	PCE, ppb
Routine Monitoring			
11/29/99	1240	83	7
12/01/99	1156	56	ND
12/02/99	1022	67	ND
12/06/99	1402	93	ND
12/07/99	1355	120	ND
12/09/99	0942	78	ND
12/15/99	1124	75	1
12/17/99	1124	72	6
12/22/99	1052	64	ND
01/07/00	0835	54	ND
01/11/00	1328	64	ND
01/13/00	1140	76	ND
01/21/00	1124	75	ND

HN-14I

SAMPLE DATE	SAMPLE TIME	TCE, ppb	PCE, ppb
Routine Monitoring			
11/29/1999	1446	490	ND
12/1/1999	1407	450	ND
12/2/1999	1137	600	ND
12/6/1999	1600	930	ND
12/7/1999	1211	1,700	8
12/9/1999	1037	1,350	9
12/15/1999	1211	670	3
12/17/1999	1322	460	ND
12/22/1999	1145	345	3
Lab Result 12/27/99	1210	980	13
1/7/2000	0912	540	18
1/11/2000	1359	300	ND
1/13/2000	1203	430	5
1/21/2000	1257	290	30
1/27/2000	1138	760	ND

NA - Not Analyzed
ND - Not Detected

TABLE 9
NAWC - Warminster, PA
Analytical Results for HN-59S/I

HN-59S

SAMPLE DATE	SAMPLE TIME	TCE, ppb	PCE, ppb
Routine Monitoring			
11/30/1999	0900	96	ND
12/1/1999	1105	63	ND
12/2/1999	1417	130	ND
12/6/1999	1251	180	ND
12/7/1999	1119	580	ND
12/9/1999	1132	590	ND
12/15/1999	1531	300	ND
12/17/1999	0907	185	ND
12/22/1999	1418	85	ND
12/27/1999	1348	180	NA
12/28/1999	1353	270	NA
12/30/1999	0845	490	NA
1/4/2000	1038	410	NA
1/5/2000	0912	170	NA
1/7/2000	1134	100	ND
1/11/2000	1102	170	ND
1/13/2000	1104	220	ND
1/21/2000	0936	115	ND
1/26/2000	1320	127	18

HN-59 I

SAMPLE DATE	SAMPLE TIME	TCE, ppb	PCE, ppb
Routine Monitoring			
11/30/1999	1040	770	9
12/1/1999	1006	810	ND
12/2/1999	1452	860	ND
12/6/1999	1155	1,560	14
12/7/1999	1032	2,400	13
12/9/1999	1222	3,800	60
12/15/1999	1441	1,200	75
12/17/1999	959	1,030	47
12/22/1999	1330	840	12
12/27/1999	1424	1,900	NA
12/28/1999	1306	2,070	NA
12/30/1999	0921	550	NA
1/4/2000	1117	2,140	NA
1/5/2000	0948	2,175	NA
1/7/2000	1210	850	ND
1/11/2000	1025	1,000	35
1/13/2000	1015	785	4
1/21/2000	0902	630	27
1/26/2000	1245	1,270	63

NA - Not Analyzed
ND - Not Detected

FIGURE 8
NAWC - OFF-SITE AREA A
Comparison of Lab vs. Field GC Results

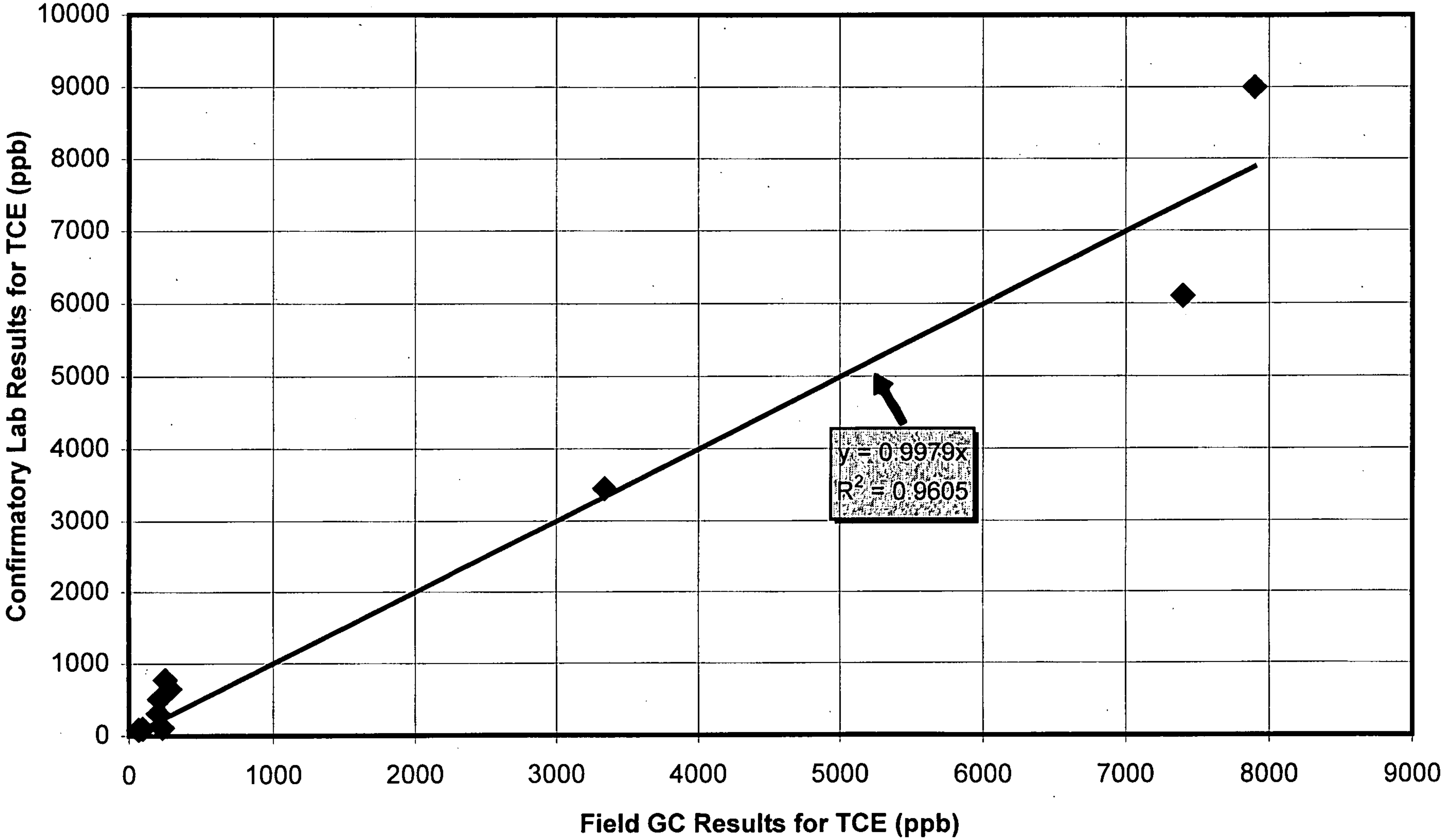
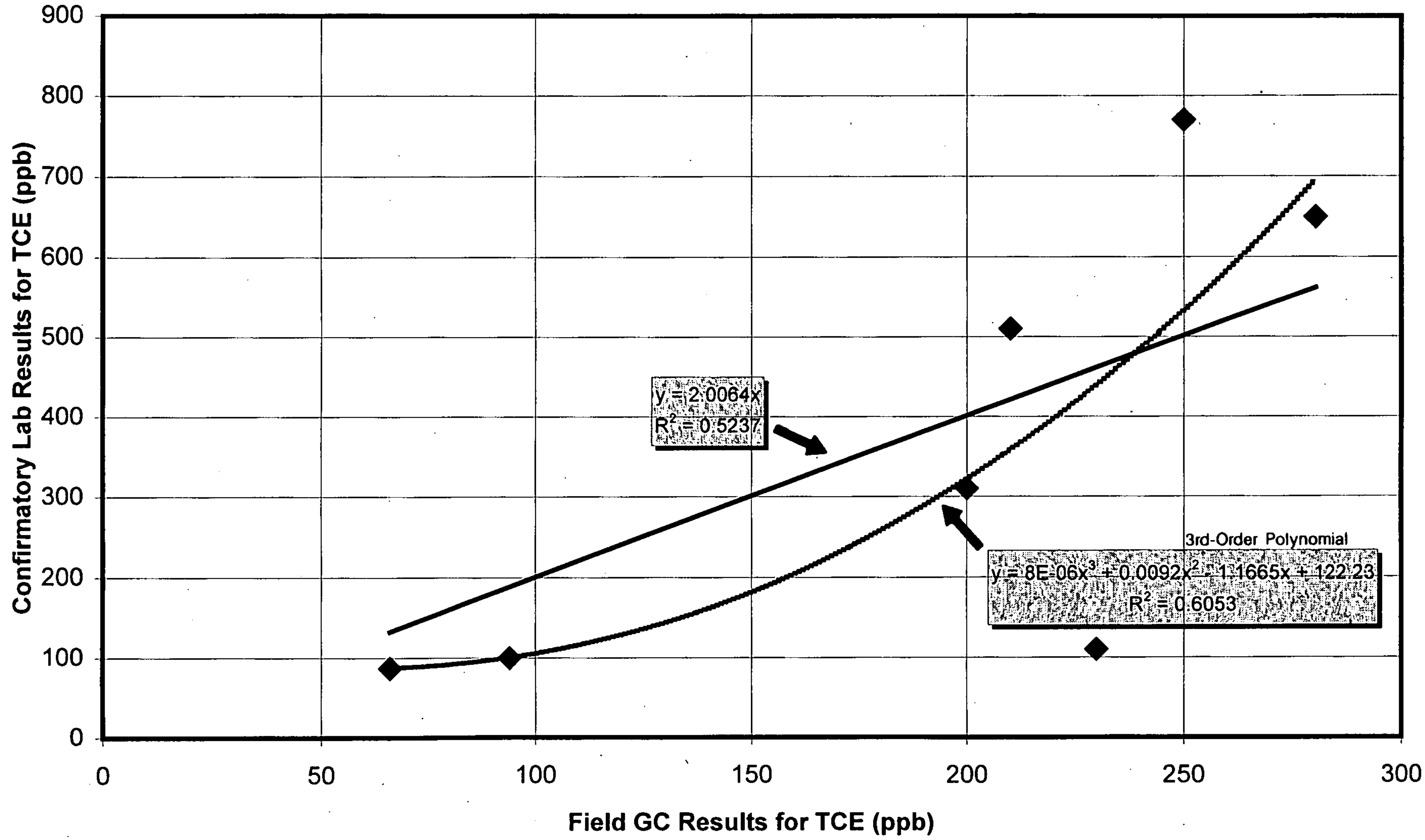


FIGURE 9
NAWC - OFF-SITE AREA A
Comparison of Lab vs. Field GC Results



maintenance) during the drilling/testing program: from December 6, 1999 at 1024 hours to December 7, 1999 at 1453 hours; and, from January 19, 2000 at 0817 hours to January 21, 2000 at 1610 hours. None of the measured TCE/PCE concentrations in off-site boreholes are indicative of potential nearby free-product (less than 1% of TCE/PCE solubility limits).

During each yield test, groundwater discharge samples were collected at one to two hour intervals from a sample port at the wellhead. Samples from HN-68 and HN-72 exhibited the highest off-site concentrations of TCE, ranging from 1 to 7.4 ppm and 7.5 to 10.7 ppm, respectively. The field screening results at HN-68 were highest immediately after the well was yield tested (5.8 to 7.4 ppm), and declined to 1-3 ppm by the end of January 2000. TCE concentrations at HN-67, HN-69, HN-70, and HN-71 generally ranged from 100-300 ppb. An isolated packer sample collected below 80 feet depth at HN-67 exhibited TCE at 430 ppb, an order of magnitude higher than samples collected from the entire exposed borehole. A packer sample from below 80 feet depth at HN-71 exhibited TCE at 770 ppb, compared to 110 ppb from the interval above 75 feet depth.

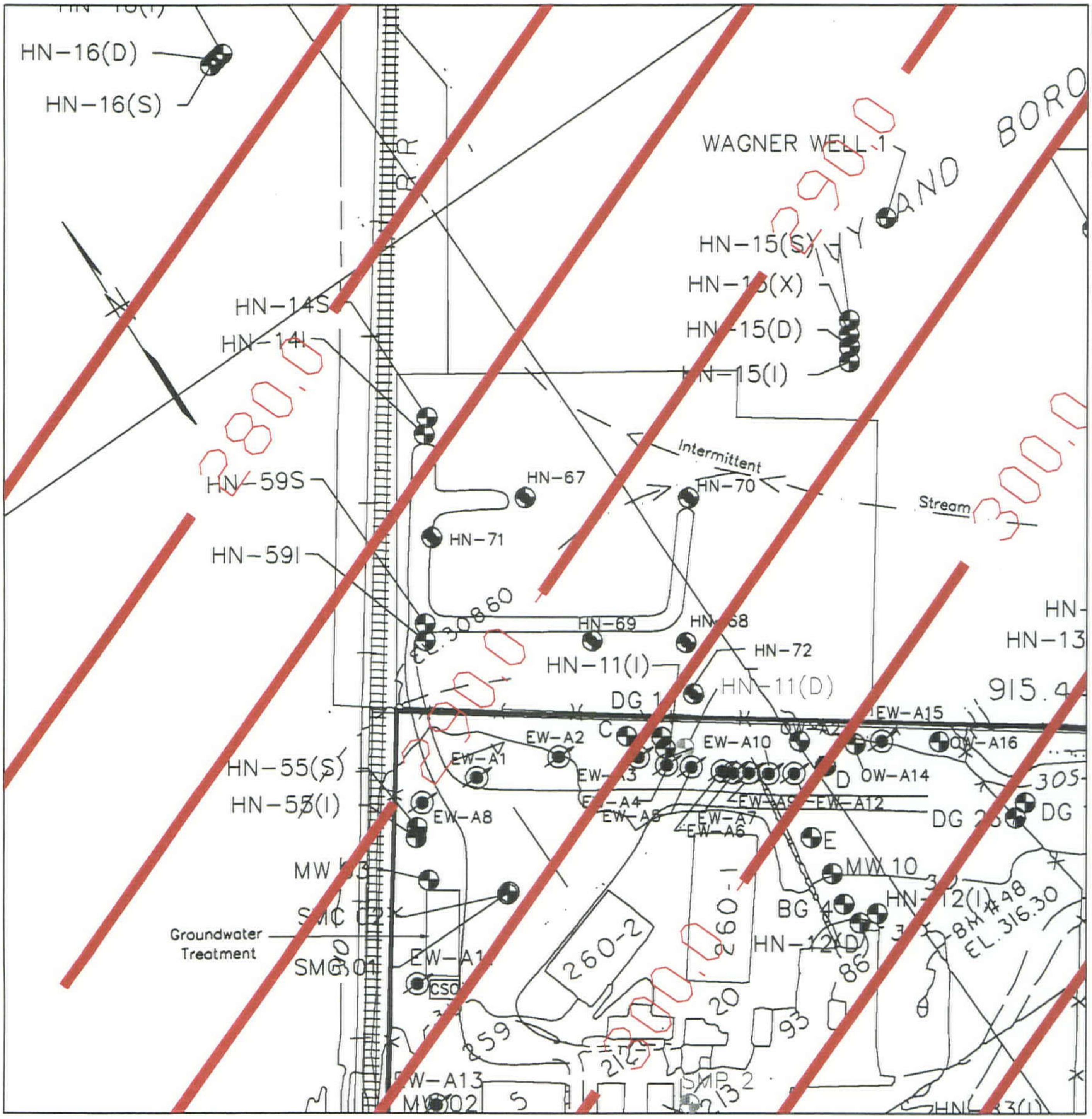
5.0 CAPTURE ZONE ANALYSIS AND PROPOSED WELL COMPLETIONS

Based on potentiometric maps presented in the Pre-Start up and Start-up Performance Monitoring Report prepared by EA Engineering Science and Technology for the Navy, dated December 1999, and water level/capture zone influences measured during yield tests at the off-site boreholes, the previous groundwater flow/capture zone model for Area A was modified.

QuickFlow, a 2D analytical groundwater flow model, has been used to conceptualize groundwater capture by the Area A extraction well network. It should be recognized that groundwater flow modeled in QuickFlow assumes uniform, isotropic hydrogeologic conditions. Although the hydrogeology at Area A consists of layered, fractured bedrock strata (far from uniform, isotropic conditions), the nature and extent of fracturing in the shallow bedrock has resulted in hydraulic performance somewhat similar to "ideal" conditions. The QuickFlow output should be viewed as a simplified, conceptual model, not an exact replication of actual site conditions.

Figure 10 illustrates a simplified version of the non-pumping potentiometric surface in the shallow, confined aquifer at Area A. This map is based on the 0.03 feet/foot horizontal gradient present in Figure 3-7 of EA's Performance Monitoring Report.

Figure 11 illustrates the capture zone produced by the current Area A extraction well network. This figure varies slightly from previous interpretations (Figure 7-1 of the Installation/Testing of Area A Groundwater Extraction Wells report prepared by Foster Wheeler for the Navy, dated June 30, 1999), due to application of a slightly flatter horizontal gradient (0.04 feet/foot was used previously). Figure 11 indicates that the Area A extraction well network capture zone does encompass a portion of the off-site area immediately northeast of the extraction wells. Since yield tests in off-site boreholes showed influence (drawdown) in Area A monitoring wells, it is reasonable to assume the extraction wells provide some influence in the off-site area.



0 150 300
SCALE IN FEET

Monitoring Wells

Extraction Wells

Newly-Installed

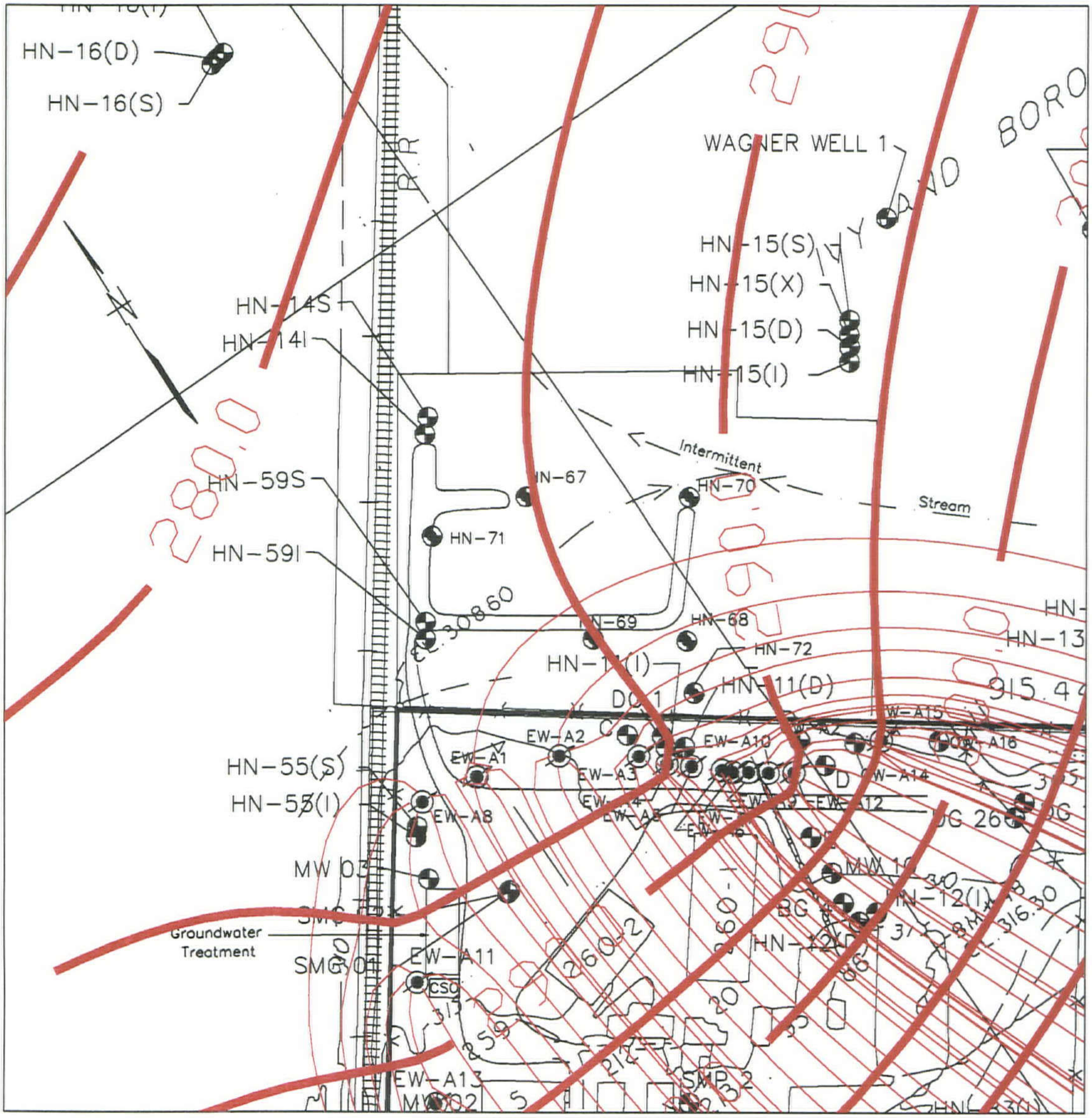
CADD FILE: warminster\pipeline\area-a\newa.dwg

Note: Approximation of map/gradient presented in Figure 3-7, Pre-Startup and Startup Performance Monitoring Report, EA, December 1999

U.S. Navy RAC
NAWC WARMINSTER - AREA A

Figure 10
Non-Pumping Potentiometric Surface at Area A, Shallow Aquifer
Horizontal Gradient = 0.03 ft/ft

FOSTER WHEELER ENVIRONMENTAL CORPORATION



0 150 300

SCALE IN FEET

Monitoring Wells

Extraction Wells

Newly-Installed

Note: Basemap Modified from Brown & Root Environmental, Drawing No. 1412G103.dwg
Dated: 02/26/1998

CADD FILE: warminster\pipeline\area-a\newa.dwg

U.S. Navy RAC
NAWC WARMINSTER - AREA A

Figure 11

Revised Conceptual View of the Area "A" Capture Zone

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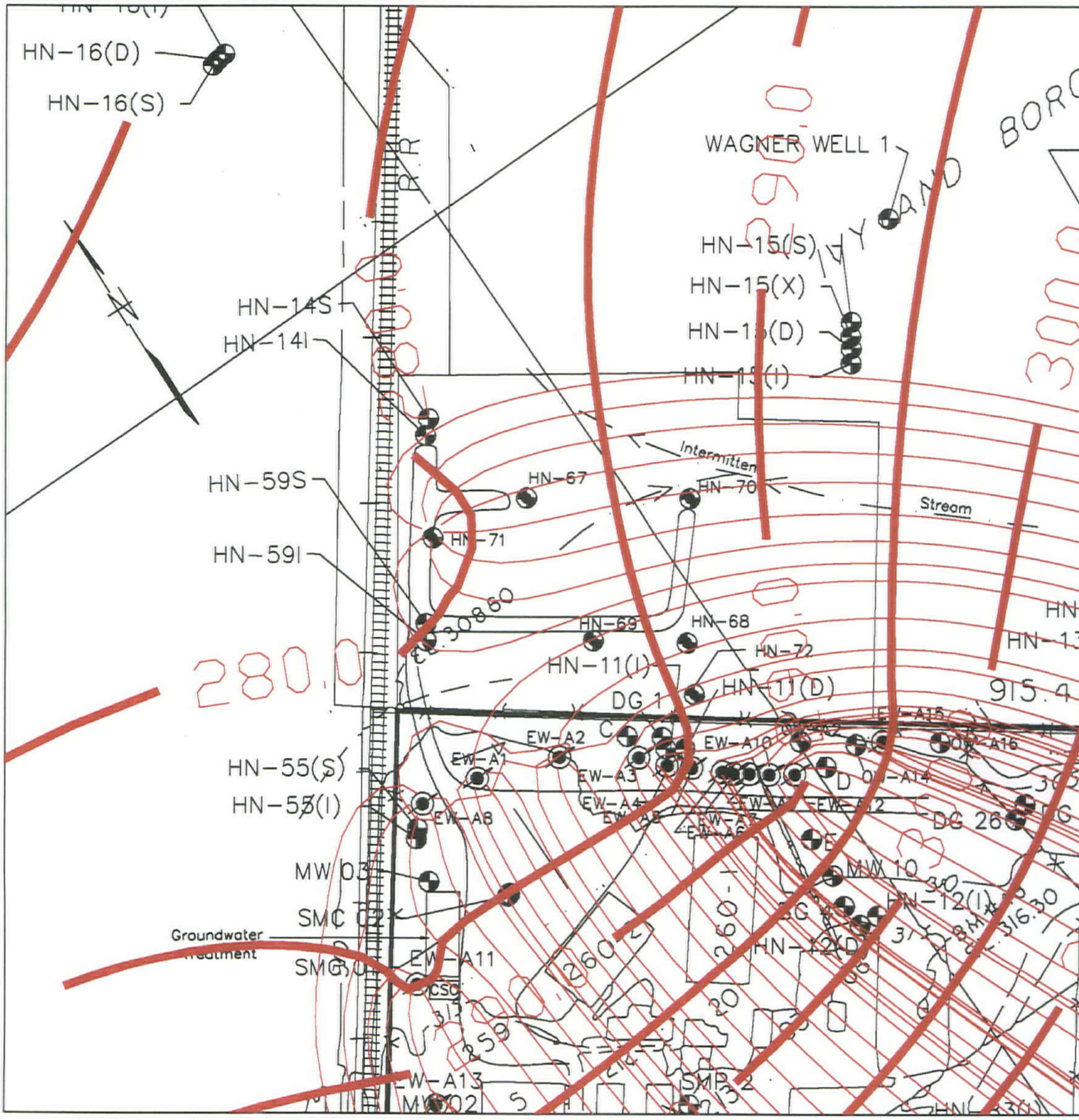

Legend

- Monitoring Wells
- Extraction Wells
- Newly-Installed

0 150 300
SCALE IN FEET

Note: Basemap Modified from Brown & Root Environmental, Drawing No. 1412G103.dwg
Dated: 02/26/1998

CADD FILE: warminster\pipeline\area-a\newa.dwg

U.S. Navy RAC
NAWC WARMINSTER - AREA A

Figure 12
Area "A" Capture Zone With HN-71 Added at 10 GPM

FOSTER WHEELER ENVIRONMENTAL CORPORATION

After reviewing and discussing the drawdown/ROI measured during the yield tests in the off-site boreholes, and the revised QuickFlow modeling, the TEG agreed that adding HN-71 to the existing Area A extraction well network would be sufficient to fully capture elevated TCE in groundwater across the northern portion of the adjacent off-site property. Based on that decision, and recommendations from the USGS, USEPA, and TetraTech NUS, the other five off-site boreholes will be used as additional monitoring wells, completed as follows:

- HN-67: Shallow and deep well pair, with 2-inch diameter PVC screens located at 24-48 feet and 76-99 feet bgs.
- HN-68: Shallow and deep well pair with 2-inch diameter PVC screens located at 35-45 feet bgs and 62-76 feet bgs.
- HN-69: Shallow and deep well pair with 2-inch diameter PVC screens located at 42-58 feet and 66-102 feet bgs.
- HN-70: Shallow, intermediate, and deep wells, with 2-inch PVC screens located at 32-42, 52-62, and 70-80 feet bgs.
- HN-72: Single completion well, with 2-inch PVC screen located at 44-80 feet bgs.

Screens will consist of 0.03-slot, with Morie #2 (or equivalent) sandpack two feet above and below each screen. A two-foot thick bentonite seal will be placed atop each sandpack, with the remainder of the well annulus filled with a bentonite-cement grout. Bids for this work are currently being reviewed by Foster Wheeler. These additional off-site monitoring wells should be completed by mid-March 2000.

Ten-inch diameter, black steel casing was installed at HN-71 to a depth of 75 feet bgs. The annulus was filled with a bentonite-cement grout. The bottom of the borehole (75-107 feet) will remain an open-hole completion. The well will be fitted with a downhole submersible pump capable of providing 10-15 GPM. Associated piping and a surface vault will be installed to connect this well to the existing Area A extraction network.