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DEPARTMENT OF THE AIR FORCE

HEADQUARTERS 833D COMBAT SUPPORT GROUP (TAC)

HOLLOMAN AIR FORCE BASE NM 88330-5000

JUN 1990

REPLY TO ATTN OF: 833 CSG/DEV

SUBJECT: Groundwater Reports

TO: Mr. Boyd Hamilton
Hazardous Waste Bureau
Environmental Improvement Division
New Mexico Health and Environment Department
1190 St Francis Dr
Santa Fe, NM 87503

1. Enclosed please find the background contamination indicator parameter summary statistics for upgradient wells and comparisons with data from the first semi-annual groundwater sampling episode for the sewage treatment lagoons monitoring wells at Holloman AFB, NM. This report fulfills the annual reporting requirement outlined in 40 CFR 265.93(b).

2. We understand the NMEID needs the report presented on their own forms. The contractor is presently in the process of reaccomplishing the report on the required forms. We will submit said report as soon as we receive it back.

3. If you have any questions or comments, please contact Sharon Moore at 479-3931.

HOWARD E. MOFFITT
Deputy Base Civil Enginee

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BACKGROUND CONTAMINATION INDICATOR PARAMETER SUMMARY STATISTICS FOR UPGRADIENT WELLS AND COMPARISONS WITH DATA FROM THE FIRST SEMI-ANNUAL GROUND WATER SAMPLING EPISODE SEWAGE TREATMENT LAGOONS MONITORING WELLS HOLLOMAN AIR FORCE BASE, NEW MEXICO

Prepared for:

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Under contract with:

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June 1990

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1.0 INTRODUCTION

International Technology Corporation (IT) is the prime Architect-Engineer (A-E) contracted by the U.S. Army Corps of Engineers, Omaha District, to implement a ground water investigation of the sewage lagoons and Lakes Holloman and Stinky, Holloman Air Force Base, New Mexico. The investigative program is being performed under Contract No. DACW45-88-D-0008. As part of the investigative program ground water sampling has been conducted five times to date, once during each of the months of August, September, November, and December, 1989, and again in January, 1990. Ground water sampling was conducted in accordance with the A-E Quality Control and Sampling Plan (A-E QCP/SP) for Groundwater Study and Monitoring Program, Holloman Air Force Base, New Mexico (IT, 1989a).

1.1 REQUIREMENTS OF 40 CFR 265.92

The requirements of 40 CFR 265.92 specify that during the first year of sampling initial background concentrations or values must be established [40 CFR 265.92(c)(1)] for the parameters characterizing the suitability of the ground water as a drinking water supply (40 CFR 265, Appendix III), the constituents characterizing ground water quality [40 CFR 265.92(b)(2)] and ground water contamination indicator parameters [40 CFR 265.92(b)(3)] for all wells. The sewage treatment lagoons at Holloman Air Force Base had been in operation for some years prior to the initialization of this ground water monitoring program. Consequently, all monitoring wells were sampled during each sampling episode but, as the sewage treatment lagoons are an existing facility, only the upgradient wells are evaluated for establishing background constituent concentrations. According to the regulations, background water monitoring is to be performed by sampling quarterly for the first year. The Holloman Air Force Base sewage treatment lagoons monitoring wells, however, were sampled on an accelerated schedule during August, September, November, and December of 1989. The data collected during these sampling episodes, as previously reported by Radian (1989) and IT (1989b; 1990a, b) represent establishment of initial background concentrations as required by 40 CFR 295.92(c)(1).

Additionally required in 40 CFR 265.92(c)(2), initial background arithmetic means and variances for the contamination indicator parameters [40 CFR 265.92(b)(3)] are to be calculated for upgradient wells using at least four replicate measurements for each sample and pooling the respective parameter measurements obtained during the first year. Data presented later in this report comply with the requirements of 40 CFR 265.92(c)(2).

Following the first year of sampling which meets the requirements of 40 CFR 265.92(b) and (c), the sampling frequencies for the constituents characterizing ground water quality and the contamination indicator parameters are established in 40 CFR 265.92(d). Parameters characterizing ground water quality must be sampled annually [40 CFR 265.92(d)(1)]. Ground water contamination indicator parameters must be sampled semi-annually [40 CFR 265.92(d)(2). In January, 1990, the annual and semi-annual sampling requirements were met. These data were reported by IT (1990c).

1.2 REQUIREMENTS OF 40 CFR 265.93

The calculation of arithmetic means and variances for the parameters indicating ground water contamination are required in 40 CFR 265.93(b) based on at least four replicate measurements of the respective parameters at each well monitored during the semi-annual sampling episodes. The first semi-annual ground water sampling episode at Holloman Air Force Base was conducted in January 1990, one month after completion of the first four monthly sampling episodes. The summary statistics calculated from the first semi-annual sampling are to be compared to the initial background means by use of the Student's t-test at the 0.01 level of significance (alpha) to determine statistically whether significant increases (and decreases in the case of pH) have occurred with respect to background.

In this report summary statistics are calculated for the contamination indicator parameters at upgradient wells (representing background) during the first four monthly sampling rounds by pooling the monthly replicate averages. These background summary statistics are compared with the replicate averages calculated for all wells sampled during the January, 1990, first semi-annual sampling episode. As specified in the A-E QCP/SP, comparisons of the January, 1990, data with the individual upgradient wells, MW-1 and S-2, are reported here. Additionally, a final set of comparisons are made comparing the January data against a pooling of all upgradient well data. As proposed in the A-E QCP/SP the average replicate t-test is the Student's t-test utilized here for the background versus semi-annual sampling data comparisons.

2.0 METHODOLOGY

The methodology for performing the averaged replicate t-test statistical comparison between background parameter values at the upgradient wells and the January, 1990, data involve three distinct steps. First, the data from the upgradient wells collected during the first four sampling rounds are listed and the summary statistics calculated. Second, the data from the January, 1990, sampling episode are listed and summary statistics calculated. Third, using the summary statistics, the average replicate t-test is applied to make comparisons between the two data sets. Prior to discussing the results of these comparisons in Section 3.0, discussions concerning the quality and accuracy of the data themselves and of the procedures employed in this report are included in this section. The methodology used in this report follows closely the example data and calculations found in RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD), Appendix B (National Water Well Association, 1986).

2.1 TABULATION OF BACKGROUND FIELD AND LABORATORY DATA FROM THE UPGRADIENT WELLS

Table 1 is a compilation of contamination indicator parameter data collected in the field and laboratory for the upgradient wells MW-1 and S-2 during ground water sampling activities in August, September, November, and December, 1989. The contamination indicator parameters listed include pH and specific conductance, both determined in the field, total organic carbon (TOC) and purgeable organic halides (POX) which were measured in samples sent to analytical laboratories. The data are reported exactly as returned from the laboratories with respect to significant digits. However, laboratory conventions for expressing "less than detection limit" values (ND, U, <, etc.) have been standardized in this report using the "less than" (<) symbol.

The values listed in Table 1 resulted from field measurement and sample analysis by personnel from two different A-E contractors and their laboratories. All data collected during the first sampling episode in August, 1989, resulted from the work of Radian Corporation, Austin, Texas (Radian, 1989). Subsequent sampling episodes were completed by IT. Discussions which follow concerning field measurements, instrumental accuracies, laboratory method detection limits, etc. are only applicable to the data collected by IT.

pH MEASUREMENTS

Measurements for pH were taken using an Orion SA 250 pH meter in automatic temperature compensation mode. The pH meter was calibrated daily prior to sampling, at a minimum, and calibration was checked against standard pH 7.00 buffer solution prior to initiating sampling at each well. The pH meter calibration was checked again against three standard buffers (pH 4.01, 7.00, and 10.00) at the end of the sampling day. Four measurements were taken from separate bailings after purging approximately five well volumes of water and collecting samples at each well. pH measurements were recorded to the nearest one-hundredth pH unit as indicated in Table 1. pH is a logarithmic scale (negative logarithm of the hydronium (H_3O^+) ion concentration, conventionally referred to in this report as hydrogen ion concentration or just hydrogen). In order to compare pH values using the t-test, pH values are converted to their equivalent hydrogen ion concentrations (an arithmetic scale). Table 2 shows the upgradient background pH values converted to hydrogen ion concentrations using the formula:

$$\text{micro moles/liter } (\mu \text{ mol/l}) \text{ Hydrogen} = -\log(\text{pH}) \times 10^6 \mu \text{ mol/Mole}$$

All subsequent pH values are recalculated as hydrogen ion concentrations in micro moles per liter (μ mol/l) prior to calculating statistics in this report.

SPECIFIC CONDUCTANCE

Measurements of specific conductance were taken using a Cole Palmer model 1418-60 conductance meter in automatic temperature calibration mode. All measurements were taken on the instrument's 0 - 200,000 μ mhos/cm @ 25 °C scale. The instrument was calibrated daily prior to beginning well sampling using a standard reference solution at the scale midpoint. Calibration was rechecked at the end of the sampling day. Four replicate measurements were taken at each well following purging and chemistry sample collection. The Cole Palmer specific conductance meter has a three digit display. Consequently, conductance values exceeding 1000 μ mhos/cm are read on the display and multiplied by a scale factor. As the values reported in Table 1 show, rounding to the tens and hundreds place is the typical accuracy for specific conductance measurements from the Holloman well samples.

<u>TOTAL ORGANIC CARBON (TOC) AND PURGEABLE ORGANIC HALIDES (POX)</u>

The Table 1 values for TOC and POX resulted from laboratory analysis of samples collected in the field. The data are reported here exactly as reported by the laboratories with respect to significant digits. The numerous data coding conventions employed by the various laboratories to identify limits of detection or values less than detectable (U, ND, <, etc. representing undetected, not detected, or "less than" some detection limit value, for example) are not reported here exactly as they were reported by the analytical laboratories. Rather all less than detectable values are represented in this report by the "less than" symbol (<), indicating that the constituent was not detected at the lower limit of detection value following the less than symbol.

TOC and POX values for August, 1989, were determined by Radian Corporation. TOC analyses for September and December, 1989, were completed at the IT Analytical Services (ITAS) Middlebrook (Knoxville), Tennessee laboratory. TOC results for November, 1989, are from the ITAS Oak Ridge, Tennessee laboratory. Results reported by the different laboratories account for the differences in significant digits reported in the Table 1 TOC results.

POX analyses were also performed on the samples collected in November, 1989, at Radian Corporation, Austin, Texas, at the request of IT Corporation. September POX analyses were performed at ITAS Austin, Texas laboratory. The December, 1989, POX analyses were performed at the ITAS Oak Ridge, Tennessee laboratory. The various laboratories employed account for the variations in reported significant digits and variable detection limits for the POX results listed in Table 1.

During the POX analyses performed in September, 1989, the laboratory substituted an incorrect analytical method for the method specified in the A-E QCP/SP. The November and December POX analyses exceeded sample holding times prior to analysis. Additionally, the November and December samples contained an incorrect sample preservative which required neutralization prior to analysis. While the validity of these data may be suspect, the values reported are generally in agreement with the POX values obtained from the January, 1990, sample analyses which had no holding time or preservative problems.

2.2 CALCULATION OF BACKGROUND SUMMARY STATISTICS FOR UPGRADIENT WELLS

Summary statistics calculated for each month's replicate measurements for the upgradient wells MW-1 and S-2 during the first four episodes are listed in Tables 3, 4, 5, and 6. Each table lists one contamination indicator parameter: Table 3 displays hydrogen (pH) data; Table 4 displays specific conductance data, Table 5 displays TOC data; and Table 6 displays POX data.

The column entries in Tables 3 through 6 include the well name and month sampled; N, representing the number of that month's measurements reported above a limit of detection; PROPORTION < DL, listing the proportion of that months measurements which were reported less than the detection limit; MEAN, or arithmetic average; VARIANCE, listing calculated sample variance; STANDARD DEVIATION, listing calculated sample standard deviation; and C.V., listing calculated coefficient of variation. Methods of calculating the summary statistics and example calculations are presented below.

Values for the monthly means are simple arithmetic averages calculated by summing all the measurements and dividing by a count of the measurements. In cases where some of the measurements were less than the detection limit, values of one half of the reported detection limit are used in the summary calculations. When all measurements for that month are less than a detection limit, the detection limit itself is reported as the replicate mean and calculation of further summary statistics is not applicable. Calculated mean values are rounded to the number of least significant digits reported in that month's replicate data. An example of the calculation of the monthly replicate mean using the specific conductance measurements for well MW-1 collected in November, 1989, is shown below.

Example calculation of the November, 1989, specific conductance mean from four replicate measurements well MW-1:

Equation:

$$\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}$$

where

$\bar{y}$ = replicate average (mean)

y_i = concentration measurement from this well, MW-1, this sampling episode, November 1989, sum y_i from i = i to n, where y_i = individual concentration or specific conductance measurement

n = number of measurements

Calculation (units are μ mhos/cm @ 25°C):

(59,100 μ mhos/cm + 59,600 μ mhos/cm + 60,100 μ mhos/cm + 60,100 μ mhos/cm) / 4 = 59,725 μ mhos/cm which rounds to the original data accuracy of 59,700 μ mhos/cm.

Variance is calculated as the sample variance and is a measure of how dispersed the individual measurements are about the mean. The equation for sample variance and an example calculation using the same data from above follows.

Equation:

$$s^2 = \frac{\sum_{i=1}^{n} (y_i - \bar{y})^2}{n - 1}$$

where

s^2 = sample variance

$\bar{y}$, y_i, and n are as before.

Calculation:

(59,100 μ mhos/cm - 59,725 μ mhos/cm)^2 + [(59,600 μ mhos/cm - 59,725 μ mhos/cm)^2 + [(60,100 μ mhos/cm - 59,725 μ mhos/cm)^2 (60,100 μ mhos/cm - 59,725 μ mhos/cm)^2 / (4-1) = 229,167 μ mhos^2/cm^2

which rounds to the original data accuracy of 229,200 μ mhos^2/cm^2.

Standard deviation is calculated as the sample standard deviation. Since the variance calculation returns the measurement units as squared values, the calculation of standard deviation takes the square root of the variance and returns a measurement of dispersion about the mean in units equivalent to the original data.

Equation:

$$s = \sqrt{s^2}$$

where

s = sample standard deviation
s^2 = as previously stated.

Calculation:

$$\sqrt{229{,}167\ \mu\ \text{mhos}^2/\text{cm}^2} = 479\ \mu\ \text{mhos/cm}$$

which rounds to the original data accuracy of 500 μ mhos/cm.

All calculations of the summary statistics mean, variance, and standard deviation in this report were calculated using commercially available computer spreadsheet software. Means, variances, and standard deviations were calculated from tables containing the raw data (and assumed data in the case of less than detection limit values) by the use of "canned" functions or subroutines built into the spreadsheet software. Consequently, and as in the example calculations just provided, intermediate results are not rounded before being input to subsequent calculations and are in most cases carried to ten or twelve decimal places internally in the computer software. There is a possibility that recalculation of the summary statistics provided here with hand calculators or other means could disclose slight discrepancies in the results due to calculator or software rounding peculiarities.

The final summary statistical value describing the replicate measurements on Tables 3 through 6 is coefficient of variation (C.V.). Coefficient of variation is a gross indicator of how well the distribution of measurements follows the standard normal bell-shaped curve. Coefficient of variation is a percentage measure calculated by dividing the standard deviation by the mean, times 100. Generally C.V.'s less than one are considered to indicate that the data distribution probably does not deviate from a normal distributional curve. The corollary is not necessarily true, that C.V.'s greater than one indicate a non-normal distribution. Small sample sizes, as is the case with the replicate Holloman well data presented here, can exhibit C.V.'s greater than one due to the limited data set, but this does not indicate that the distributions are non-normal. Values for the coefficient of variation in this report are calculated using the rounded means and standard deviations shown in the summary statistics tables and are themselves rounded to two decimal places. An example calculation for C.V. follows using the same November, 1989, specific conductance data from well MW-1.

Equation:

$$C.V. = (s / \bar{y}) \times 100$$

where

C.V.	=	coefficient of variation
s, $\bar{y}$	=	as previously stated.

Calculation:

$$(500\ \mu\ \text{mhos/cm} / 59{,}700\ \mu\ \text{mhos/cm}) \times 100 = 0.84.$$

Table 7 lists results of pooling the summary statistics calculated for each month's sampling at the upgradient wells during the first year (Tables 3 through 6) and lists summary statistics calculated using these replicate averages. Table 7 shows background pooled summary statistics for the upgradient wells, MW-1 and S-2, and all upgradient wells combined. Data presented Table 7 comply with the requirements of 40 CFR 295.92(c)(2) for calculating the arithmetic means and variances of contamination indicator parameters at the upgradient wells during the first year of sampling.

The methods of calculation applicable to Table 7 are identical to those previously described for Tables 3 through 6 except that instead of using the individual replicate measurements the means of the replicates measured each sampling month, August through December, 1989, are used in the calculations.

As described in Section 2.5 of this report, the means for the contamination indicator parameters from the upgradient wells listed in Table 7 are compared with the replicate averages calculated from all wells sampled during the first semi-annual sampling episode (January 1990) in the averaged replicate t-test. The purpose of the average replicate t-test is to evaluate whether or not contamination has occurred downgradient of the Holloman Air Force Base sewage lagoons.

2.3 TABULATION OF FIRST SEMI-ANNUAL FIELD AND LABORATORY DATA FROM ALL WELLS

Table 8 lists contamination indicator parameter data collected from all wells during the first semi-annual sampling episode in January, 1990. Four replicate measurements of pH and specific conductance were collected using instrumentation and procedures identical to the September through December monthly samplings at each well. An additional column in Table 8 shows the field pH measurements converted to hydrogen ion concentrations in micro moles per liter.

Laboratory analyses for TOC and POX on the January, 1990, well samples were made in quadruplicate. Analyses for TOC were completed at the ITAS Middlebrook (Knoxville), Tennessee laboratory. All TOC sample concentrations were quantifiable above the detection limit with the exception of replicate number four of the samples from well S-4. Samples submitted to the ITAS Cincinnati, Ohio laboratory were forwarded to the ITAS Oak Ridge, Tennessee laboratory for POX analysis. All analysis results for POX were reported as less than detectable at 0.010 milligram per liter (mg/l) as chloride in the January, 1990, samples.

2.4 CALCULATION OF SUMMARY STATISTICS FROM THE FIRST SEMI-ANNUAL SAMPLING EPISODE, ALL WELLS, JANUARY 1990

Table 9 contains the results of summary statistics calculations for the contamination indicator parameters at all wells sampled during the first semi-annual sampling episode in January, 1990. Mean, variance, standard deviation, and coefficient of variation values are listed for each parameter (hydrogen, specific conductance, TOC, and POX) at each well, calculated from the data listed in Table 8. Methods of calculation are identical to those used, and previously discussed. The data listed in Table 9 comply with the requirements of 40 CFR 265.93(b) for calculation of means and variances of at least four replicate measurements of the contamination indicator parameters taken at all wells during the semi-annual sampling episodes.

The means for the replicate measurements of the contamination indicator parameters from all wells sampled in January, 1990, listed in Table 8 are used with the pooled average replicate means and standard deviations from the upgradient background calculations (Table 7) in the averaged replicate t-test. The purpose of the average replicate t-test is to evaluate whether or not the Holloman Air Force Base sewage lagoons have caused ground water contamination.

2.5 CALCULATIONS OF THE AVERAGED REPLICATE t-TEST STATISTICAL COMPARISONS

Tables 10 through 15 calculate the average replicate t-statistic comparing the upgradient background means with the replicate sampling means from January, 1990 data. Table 10 lists the January replicate means (Y_m), the January replicate means minus the background means (Y_m - Y_b), and the calculated average replicate t-statistic for the parameters hydrogen and specific conductance comparing all wells sampled in January, 1990, with the background means from the upgradient well MW-1. Table 11 lists similar information for the parameters TOC and POX compared to the background means at upgradient well MW-1. Tables 12 and 13 follow in similar fashion comparing January replicate hydrogen and specific conductance means (Table 12) and, TOC and POX means (Table 13) with background means from the upgradient well S-2. Tables 14 and 15 make similar comparisons with all upgradient background averaged replicate values pooled together. Additional data contained on the tables include critical values for the t-statistic (t_c) from Tables 16 and 17. Calculated values of t (absolute values in the case of hydrogen) that exceed the Table 16 or 17 critical value for t (t_c) indicate that concentrations measured in the January, 1990, well samples are statistically greater (or lesser in the case of hydrogen) than the comparative background well(s) concentration. Discussions of the averaged replicate t-statistic and its calculation on Tables 10 through 15 follow below.

The methodology used in calculating the average replicate t-statistics in this report follows closely the example data and calculations found the in RCRA Ground Water Monitoring

Technical Enforcement Guidance Document (TEGD), Appendix B (National Water Well Association, 1986). The t-statistics reported in Tables 10 through 15 were calculated on a scientific pocket calculator. The average replicate t-statistic is a variant of the Student's-t statistic. However, the average replicate-t utilizes the number of background wells and background sampling rounds as an adjustment factor in the statistic. The average replicate t-statistic is described as the difference between the semi-annual sampling episode replicate mean and the upgradient background mean, divided by the background standard deviation times the square root of the quantity one plus one divided by the quantity number of the background wells times the number of background sampling episodes. An example calculation of the average replicate t-statistic comparing the specific conductance replicate mean from the January, 1990, sampling at well MW-2 with the background mean from the upgradient well MW-1 is presented.

Equation:

$$t = \frac{\bar{y}_m - \bar{y}_b}{s_b\sqrt{1 + 1/(n_b \times O_b)}}$$

where

t	=	the average replicate t-statistic for this well (MW-2), this parameter (specific conductance, and this semi-annual sampling episode January 1990)
$\bar{y}_m$	=	the mean of the replicate measurements for January 1990
$\bar{y}_b$	=	background mean for the upgradient well MW-1
s_b	=	background standard deviation for the upgradient well MW-1
n_b	=	number of background wells
O_b	=	number of background observations, or sampling episodes establishing background during the first year.

Calculation:

(5,500 μ mhos/cm - 57,500 μ mhos/cm)/(6,200 μ mhos/cm x $\sqrt{1}$ + (1/(1x4))) ≈ -7.504

Using Table 16, the number of wells sampled in January (10) and degrees of freedom associated with this t-test (3) the critical value of t (t_c) is determined to be 7.285. Since the t-statistic calculated is less than the critical value for t, there is no indication that the specific conductance in well MW-2 sampled in January is greater than well MW-1 background. In the previous example calculation the result was stated as approximate. This is due to the fact that the intermediate denominator term of the t-statistic (s_b) times the square root of (1 + 1 /(1 x 4)) has been rounded prior to completing the calculation in Tables 10 through 15. The intermediate denominator terms for a given parameter's t calculations remain constant when comparing the replicate means, and are given in the footnotes to Tables 10 through 15. All the information necessary to calculate the t-statistics are provided on the tables. Thus, t-statistics can be calculated using the information provided on the tables without the introduction of rounding errors caused by variations in hand calculators or other computational means.

Critical values for t are found in Tables 16 and 17. In the case of hydrogen (pH) where 40 CFR 265.93(b) requires the detection of increases or decreases in pH, a two-tailed table of critical values is utilized (Table 17) and the absolute value of the t-statistic compared to the critical value of t must be used. A single-tailed table of critical values for the t-statistic is utilized for comparisons of all other contamination indicator parameters and is found in Table 16. Values in these tables were excerpted from the TEGD (National Water Well Association, 1986).

3.0 DISCUSSION OF RESULTS

Results for the average replicate t-test comparisons of the January, 1990, data and the background well(s) data follow below.

3.1 JANUARY 1990 DATA COMPARED TO UPGRADIENT WELL MW-1

As indicated in Tables 10 and 11, none of the calculated t-statistics for hydrogen, specific conductance, TOC, or POX exceed the respective critical values for t. This indicates that there are no statistical increases (and decreases in the case of hydrogen) between the contamination indicator parameter values is any wells sampled in January, 1990, and the background mean values from the upgradient well MW-1.

3.2 JANUARY 1990 DATA COMPARED TO UPGRADIENT WELL S-2

As indicated in Tables 12 and 13 the upgradient well MW-1 shows statistical differences in pH and specific conductance for the replicate averages of the January 1990 sampling when compared to the upgradient well S-2 background means. This indicates that there are differences in the concentrations of these measured parameters between the two upgradient wells. This unusual occurrence may be caused by site hydrologic factors discussed in Section 4.0, below. Additionally, wells MW-6 and S-4 January specific conductance replicate average values are statistically greater than the background means at the upgradient well S-2. These comparisons are based on the fact that the calculated t-statistics exceed the Table 16 and 17 critical values of T for those wells.

3.3 JANUARY 1990 DATA COMPARED TO ALL UPGRADIENT WELLS

As indicated in Tables 14 and 15, when the January, 1990 replicate averages are compared to pooled background means and standard deviations of all upgradient wells (MW-1 and S-2) there are no indications of any January, 1990, means statistically exceeding (or statistically less than in the case of hydrogen) their respective critical values for t. Consequently, the January 1990 contamination indicator parameters show no statistical excursions above or below pooled upgradient background mean concentrations. This partially results from the increased variance of the background data set when means from the upgradient wells MW-1 and S-2 are combined. Wells MW-1 and S-2 exhibit significant differences in parameter concentrations as previously noted.

4.0 HYDROGRAPHS AND POTENTIOMETRIC SURFACE MAPS

Ground water elevations were obtained at each monitoring well prior to sampling, pursuant to 40 CFR 265.92 (e). These data were presented in the data reports for each sampling round. The data are shown in Tables 18 through 22. These data were used to construct hydrographs for each well and potentiometric surface maps of the site for each sampling period. The hydrographs and potentiometric surface maps were prepared pursuant to 40 CFR 265.93 (f), which requires evaluation of ground water surface elevations data to determine whether the requirements for locating the monitoring wells continues to be satisfied.

The hydrographs are shown in Figure 1. These were prepared by IT using the GRAPHER program (Golden Software, Inc.). All downgradient wells display an increase (two feet, or more, in most cases) in the ground water elevation over the five sampling episodes, generally with a intermediate peak in late September, 1989. Upgradient well MW-1 shows only a small September increase (less than one foot), and little overall trend over the sampling period. By contrast, upgradient well S-2 shows the only consistent increase in ground water elevation during the sampling period among all wells measured.

Potentiometric surface maps are shown in Figures 2 through 6. The contours were constructed using the SURFER program (Golden Software, Inc.). The contour grids were calculated by kriging, using an octant search method with a search radius of 285.66 and the nearest number of points equal to 10. Override options were also used to compensate for computer limitations.

The construction of the ground water surface contours is limited somewhat by the absence of well control along the eastern margin of the lagoons. The surface maps show some mounding of ground water at the north end of the lagoons (near lagoons A and C) and perhaps at the south end of the lagoons (west and south of lagoon G).

The potentiometric surface map for the January, 1990, sampling round suggests the "upgradient" well, S-2, may not be hydrologically upgradient from the lagoons and may, in fact, be influenced (at least periodically) by them. The statistically significant differences between indicator parameters at well S-2 and MW-1, the other upgradient well (Section 3.2), may be due, in part, to the effect of the lagoons. This evidence indicates that monitoring well S-2 may not meet the requirements of 40 CFR 265.91 (a); however, monitoring well MW-1 is clearly upgradient in all potentiometric surface maps. Thus, the ground water monitoring program, as currently configured, is meeting the minimum requirements of 40 CFR 265.91; i.e., at least one monitoring well is installed hydraulically upgradient from the facility.

5.0 CONCLUSIONS

A ground water monitoring system of wells was installed at the Holloman Air Force Base sewage treatment lagoons in 1989. Two wells (MW-1 and S-2) were designed as hydrologically upgradient from the lagoons and eight are hydrologically downgradient. A program of sampling

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TABLE 1

GROUND WATER CONTAMINATION INDICATOR PARAMETERS
BACKGROUND DATA FROM TWO UPGRADIENT WELLS
SAMPLED APPROXIMATELY MONTHLY
SEWAGE TREATMENT LAGOONS MONITORING WELLS
HOLLOMAN AIR FORCE BASE, NEW MEXICO
1989

MONTH	WELL	REPLICATE	pH	SPECIFIC CONDUCTANCE (µmhos/cm@ 25°C)	TOC (mg/l)	POX (mg/l, as chloride)
Aug	MW-1	1	6.53	48900	< 1.0	< 0.024
		2	6.66	48200	< 1.0	0.089
		3	6.70	48500	19	0.082
		4	6.69	48500	19	< 0.024
Sep	MW-1	1	6.73	61300	1	0.5
		2	6.72	62400	< 1	2.1
		3	6.71	62900	< 1	1.0
		4	6.72	63100	< 1	4.1
Nov	MW-1	1	6.76	59100	< 1.00	0.14
		2	6.76	59600	< 1.00	0.13
		3	6.74	60100	< 1.00	0.12
		4	6.76	60100	< 1.00	0.13
Dec	MW-1	1	6.76	59200	1	< 0.010
		2	6.73	59900	1	< 0.010
		3	6.75	59500	1	< 0.010
		4	6.74	59200	1	< 0.010
Aug	S-2	1	7.10	10450	6.2	< 0.024
		2	7.11	9750	7.3	< 0.024
		3	7.13	9570	10	< 0.024
		4	7.09	9700	5.8	< 0.024
Sep	S-2	1	7.07	11600	6	0.080
		2	7.11	11500	6	< 0.05
		3	7.13	11700	5	0.090
		4	7.12	11800	5	< 0.05
Nov	S-2	1	7.22	8900	6.71	< 0.024
		2	7.28	8400	7.13	< 0.024
		3	7.30	8500	7.02	< 0.024
		4	7.31	8400	7.02	< 0.024
Dec	S-2	1	7.25	7400	6	< 0.010
		2	7.26	6800	6	< 0.010
		3	7.23	7300	6	< 0.010
		4	7.23	7300	6	< 0.010

TABLE 2

CONVERSION OF BACKGROUND pH VALUES TO HYDROGEN ION CONCENTRATIONS IN MICRO MOLES PER LITER (μmol/l) SEWAGE TREATMENT LAGOONS MONITORING WELLS HOLLOMAN AIR FORCE BASE, NEW MEXICO 1989

MONTH	WELL	REPLICATE	pH	HYDROGEN (μmol/l)
Aug	MW-1	1	6.53	0.295
		2	6.66	0.219
		3	6.70	0.200
		4	6.69	0.204
Sep	MW-1	1	6.73	0.186
		2	6.72	0.191
		3	6.71	0.195
		4	6.72	0.191
Nov	MW-1	1	6.76	0.174
		2	6.76	0.174
		3	6.74	0.182
		4	6.76	0.174
Dec	MW-1	1	6.76	0.174
		2	6.73	0.186
		3	6.75	0.178
		4	6.74	0.182
Aug	S-2	1	7.10	0.079
		2	7.11	0.078
		3	7.13	0.074
		4	7.09	0.081
Sep	S-2	1	7.07	0.085
		2	7.11	0.078
		3	7.13	0.074
		4	7.12	0.076
Nov	S-2	1	7.22	0.060
		2	7.28	0.052
		3	7.30	0.050
		4	7.31	0.049
Dec	S-2	1	7.25	0.056
		2	7.26	0.055
		3	7.23	0.059
		4	7.23	0.059

TABLE 3

SUMMARY STATISTICS DESCRIBING THE REPLICATE MEASUREMENTS OF pH (μmol/l HYDROGEN) TAKEN DURING THE ESTABLISHMENT OF BACKGROUND CONCENTRATIONS
SEWAGE TREATMENT LAGOONS MONITORING WELLS
HOLLOMAN AIR FORCE BASE, NEW MEXICO
1989

WELL	MONTH	N	PROPORTION < DL	MEAN	VARIANCE	STANDARD DEVIATION	C.V.
MW-1	Aug	4	0	0.229	1.98E-03	0.044	19.18
	Sep	4	0	0.191	1.28E-05	0.004	2.10
	Nov	4	0	0.176	1.68E-05	0.004	2.27
	Dec	4	0	0.180	2.86E-05	0.005	2.78
S-2	Aug	4	0	0.078	9.30E-06	0.003	3.84
	Sep	4	0	0.078	2.34E-05	0.005	6.40
	Nov	4	0	0.053	2.58E-05	0.005	9.44
	Dec	4	0	0.057	3.88E-06	0.002	3.49

N = Number of values greater than detection limit.
DL = Detection Limit.
C.V. = Coefficient of Variation.

TABLE 4

SUMMARY STATISTICS DESCRIBING THE REPLICATE MEASUREMENTS OF SPECIFIC CONDUCTANCE (μmhos/cm @ 25°C) TAKEN DURING THE ESTABLISHMENT OF BACKGROUND CONCENTRATIONS SEWAGE TREATMENT LAGOONS MONITORING WELLS HOLLOMAN AIR FORCE BASE, NEW MEXICO 1989

WELL	MONTH	N	PROPORTION < DL	MEAN	VARIANCE	STANDARD DEVIATION	C.V.
MW-1	Aug	4	0	48500	82500	300	0.62
	Sep	4	0	62400	649000	800	1.28
	Nov	4	0	59700	229200	500	0.84
	Dec	4	0	59500	110000	300	0.50
S-2	Aug	4	0	9870	156560	400	4.05
	Sep	4	0	11700	16600	100	0.85
	Nov	4	0	8600	56700	200	2.33
	Dec	4	0	7200	73300	300	4.17

N = Number of values greater than detection limit.
DL = Detection Limit.
C.V. = Coefficient of Variation.

TABLE 5

SUMMARY STATISTICS DESCRIBING THE REPLICATE MEASUREMENTS OF TOC (mg/l) TAKEN DURING THE ESTABLISHMENT OF BACKGROUND CONCENTRATIONS SEWAGE TREATMENT LAGOONS MONITORING WELLS HOLLOMAN AIR FORCE BASE, NEW MEXICO 1989

WELL	MONTH	N	PROPORTION < DL	MEAN	VARIANCE	STANDARD DEVIATION	C.V.
MW-1	Aug	2	0.50	9.8	114.1	10.7	109.18
	Sep	1	0.75	0.6	0.1	0.2	33.33
	Nov	0	1.00	< 1.00	NA	NA	NA
	Dec	4	0.00	1	0	0	0.00
S-2	Aug	4	0	7.3	3.6	1.9	26.03
	Sep	4	0	6	0	1	16.67
	Nov	4	0	6.97	0.03	0.18	2.58
	Dec	4	0	6	0	0	0.00

N = Number of values greater than detection limit.
DL = Detection Limit.
C.V. = Coefficient of Variation.
NA = Not Applicable.

TABLE 6

SUMMARY STATISTICS DESCRIBING THE REPLICATE MEASUREMENTS OF POX (mg/l AS CHLORIDE) TAKEN DURING THE ESTABLISHMENT OF BACKGROUND CONCENTRATIONS SEWAGE TREATMENT LAGOONS MONITORING WELLS HOLLOMAN AIR FORCE BASE, NEW MEXICO 1989

PARAMETER	WELL	MONTH	N	PROPORTION < DL	MEAN	VARIANCE	STANDARD DEVIATION	C.V.
POX (mg/l as chloride)	MW-1	Aug	2	0.50	0.049	0.002	0.043	87.76
		Sep	4	0	1.9	2.5	1.6	84.21
		Nov	4	0	0.13	0.00	0.01	7.69
		Dec	0	1.00	< 0.010	NA	NA	NA
	S-2	Aug	0	1.00	< 0.024	NA	NA	NA
		Sep	2	0.50	0.06	0.00	0.03	50.00
		Nov	0	1.00	< 0.024	NA	NA	NA
		Dec	0	1.00	< 0.010	NA	NA	NA

N = Number of values greater than detection limit.
DL = Detection Limit.
C.V. = Coefficient of Variation.
NA = Not Applicable.

TABLE 7

SUMMARY STATISTICS DESCRIBING THE REPLICATE AVERAGES FOR UPGRADIENT WELLS BACKGROUND CONCENTRATIONS OF CONTAMINATION INDICATOR PARAMETERS SEWAGE TREATMENT LAGOONS MONITORING WELLS HOLLOMAN AIR FORCE BASE, NEW MEXICO 1989

WELL(S)	PARAMETER	N	PROPORTION < DL	MEAN[(a)]	VARIANCE	STANDARD[(a)] DEVIATION	C.V.
MW-1	Hydrogen	4	0	0.194	5.98E-04	0.024	12.37
	Sp. Cond.	4	0	57500	37949200	6200	10.78
	TOC	3	0.25	3	21	5	166.67
	POX	3	0.25	0.5	0.8	0.9	180.00
S-2	Hydrogen	4	0	0.067	1.80E-04	0.013	19.40
	Sp. Cond.	4	0	9300	3659200	1900	20.43
	TOC	4	0	7	0	1	14.29
	POX	1	0.75	0.022	0.001	0.025	113.64
All Upgradient Wells	Hydrogen	8	0	0.130	4.96E-03	0.070	53.85
	Sp. Cond.	8	0	33400	681133100	26100	78.14
	TOC	7	0.13	5	13	4	80.00
	POX	4	0.50	0.3	0.4	0.7	233.33

N = Number of values greater than detection limit.
DL = Detection Limit.
C.V. = Coefficient of Variation.
Sp. Cond. = Specific Conductance
NA = Not Applicable.
(a) Units are: hydrogen (pH), µmol/l; Sp.Cond., µmhos/cm @ 25° C; TOC, mg/l; and POX, mg/l as chloride.

TABLE 8

GROUND WATER CONTAMINATION INDICATOR PARAMETERS
FIRST SEMIANNUAL SAMPLING EPISODE
SEWAGE TREATMENT LAGOONS MONITORING WELLS
HOLLOMAN AIR FORCE BASE, NEW MEXICO
JANUARY 1990

WELL	GRADIENT LOCATION	REPLICATE	pH	HYDROGEN (μmol/l)	SPECIFIC CONDUCTANCE (μmhos/cm @25°C)	TOC (mg/l)	POX (mg/l as chloride)
MW-1	UP	1	6.57	0.269	59500	2	< 0.010
		2	6.58	0.263	59800	1	< 0.010
		3	6.58	0.263	59700	1	< 0.010
		4	6.56	0.275	60400	1	< 0.010
S-2	UP	1	7.10	0.079	5700	5	< 0.010
		2	7.09	0.081	5700	5	< 0.010
		3	7.06	0.087	5800	5	< 0.010
		4	7.07	0.085	5800	5	< 0.010
MW-2	DOWN	1	7.20	0.063	5200	4	< 0.010
		2	7.19	0.065	5200	4	< 0.010
		3	7.19	0.065	5400	4	< 0.010
		4	7.19	0.065	6200	4	< 0.010
MW-3	DOWN	1	7.06	0.087	15700	8	< 0.010
		2	7.02	0.095	15900	8	< 0.010
		3	7.01	0.098	16000	8	< 0.010
		4	7.04	0.091	15900	8	< 0.010
MW-4	DOWN	1	6.75	0.178	11900	6	< 0.010
		2	6.73	0.186	12100	6	< 0.010
		3	6.73	0.186	12300	6	< 0.010
		4	6.74	0.182	12500	6	< 0.010
MW-5	DOWN	1	6.82	0.151	15400	5	< 0.010
		2	6.80	0.158	15400	5	< 0.010
		3	6.81	0.155	15300	5	< 0.010
		4	6.82	0.151	15300	5	< 0.010
MW-6	DOWN	1	6.88	0.132	94300	4	< 0.010
		2	6.89	0.129	93600	4	< 0.010
		3	6.87	0.135	95800	4	< 0.010
		4	6.87	0.135	95400	4	< 0.010
MW-7	DOWN	1	6.80	0.158	6400	3	< 0.010
		2	6.78	0.166	6400	3	< 0.010
		3	6.77	0.170	6300	3	< 0.010
		4	6.78	0.166	6300	3	< 0.010
MW-8	DOWN	1	6.99	0.102	9600	4	< 0.010
		2	6.96	0.110	10000	4	< 0.010
		3	6.97	0.107	9700	4	< 0.010
		4	6.97	0.107	9800	4	< 0.010
S-4	DOWN	1	7.01	0.098	63600	1	< 0.010
		2	7.02	0.095	64100	1	< 0.010
		3	7.02	0.095	64500	1	< 0.010
		4	7.02	0.095	64900	< 1	< 0.010

TABLE 9

SUMMARY STATISTICS DESCRIBING THE REPLICATE MEASUREMENTS TAKEN DURING THE FIRST SEMIANNUAL SAMPLING EPISODE SEWAGE TREATMENT LAGOONS MONITORING WELLS HOLLOMAN AIR FORCE BASE, NEW MEXICO JANUARY 1990

WELL LOCATION	PARAMETER	N	PROPORTION < DL	MEAN[(a)]	VARIANCE	STANDARD[(a)] DEVIATION	C.V.
MW-1 / UP	Hydrogen	4	0	0.268	3.30E-05	0.006	2.24
	Sp. Cond.	4	0	59900	150000	400	0.67
	TOC	4	0	1	0	1	100.00
	POX	0	1.00	< 0.010	NA	NA	NA
S-2 / UP	Hydrogen	4	0	0.083	1.33E-05	0.040	4.82
	Sp. Cond.	4	0	5800	3300	100	1.72
	TOC	4	0	5	0	0	0.00
	POX	0	1.00	< 0.010	NA	NA	NA
MW-2 / DOWN	Hydrogen	4	0	0.065	1.00E-06	0.001	1.54
	Sp. Cond.	4	0	5500	226700	500	9.09
	TOC	4	0	4	0	0	0.00
	POX	0	1.00	< 0.010	NA	NA	NA
MW-3 / DOWN	Hydrogen	4	0	0.093	2.29E-05	0.005	5.38
	Sp. Cond.	4	0	15900	15800	100	0.63
	TOC	4	0	8	0	0	0.00
	POX	0	1.00	< 0.010	NA	NA	NA
MW-4 / DOWN	Hydrogen	4	0	0.183	1.47E-05	0.004	2.19
	Sp. Cond.	4	0	12200	66700	300	2.46
	TOC	4	0	6	0	0	0.00
	POX	0	1.00	< 0.010	NA	NA	NA
MW-5 / DOWN	Hydrogen	4	0	0.154	1.16E-05	0.003	1.95
	Sp. Cond.	4	0	15400	3300	100	0.65
	TOC	4	0	5	0	0	0.00
	POX	0	1.00	< 0.010	NA	NA	NA
MW-6 / DOWN	Hydrogen	4	0	0.133	8.25E-06	0.003	2.26
	Sp. Cond.	4	0	94800	1015800	1000	1.05
	TOC	4	0	4	0	0	0.00
	POX	0	1.00	< 0.010	NA	NA	NA
MW-7 / DOWN	Hydrogen	4	0	0.165	2.53E-05	0.005	3.03
	Sp. Cond.	4	0	6400	3300	100	1.56
	TOC	4	0	3	0	0	0.00
	POX	0	1.00	< 0.010	NA	NA	NA
MW-8 / DOWN	Hydrogen	4	0	0.107	1.10E-05	0.003	2.80
	Sp. Cond.	4	0	9800	29200	200	2.04
	TOC	4	0	4	0	0	0.00
	POX	0	1.00	< 0.010	NA	NA	NA
S-4 / DOWN	Hydrogen	4	0	0.096	2.25E-06	0.001	1.04
	Sp. Cond.	4	0	64300	309200	600	0.93
	TOC	3	0.25	1	0	0	0.00
	POX	0	1.00	< 0.010	NA	NA	NA

N = Number of values greater than detection limit.
DL = Detection Limit.
C.V. = Coefficient of variation.
Sp. Cond. = Specific conductance.
[(a)]Units are: hydrogen (pH), μmol/l; Sp.Cond., μmhos/cm @ 25° C; TOC, mg/l; and POX, mg/l as chloride.

TABLE 10

RESULTS OF THE AVERAGED REPLICATE t-TEST COMPARING BACKGROUND HYDROGEN (pH) AND SPECIFIC CONDUCTANCE DATA FROM THE UPGRADIENT WELL MW-1 WITH DATA COLLECTED DURING THE FIRST SEMIANNUAL SAMPLING SEWAGE TREATMENT LAGOONS MONITORING WELLS, HOLLOMAN AIR FORCE BASE, NEW MEXICO JANUARY 1990

	HYDROGEN (μmol/l)			SPECIFIC CONDUCTANCE (μmhos/cm @ 25°C)		
WELL	$\bar{y}_m$	$\bar{y}_m - \bar{y}_b$	t	$\bar{y}_m$	$\bar{y}_m - \bar{y}_b$	t
MW-1	0.268	0.074	2.741	59,900	2,400	0.346
S-2	0.083	-0.111	-4.111	5,800	-51,700	-7.460
MW-2	0.065	-0.129	-4.778	5,500	-52,000	-7.504
MW-3	0.093	-0.101	-3.741	15,900	-41,600	-6.003
MW-4	0.183	-0.011	-0.407	12,200	-45,300	-6.537
MW-5	0.154	-0.040	-1.481	15,400	-42,100	-6.075
MW-6	0.133	-0.061	-2.259	94,800	37,300	5.382
MW-7	0.165	-0.029	-1.074	6,400	-51,100	-7.374
MW-8	0.107	-0.087	-3.222	9,800	-47,700	-6.883
S-4	0.096	-0.098	-3.630	64,300	6,800	0.981

$\bar{y}_m$ = Monitor well replicate average for January 1990 sampling results.

$\bar{y}_b$ = Well MW-1 background average, S_b = well MW-1 background standard deviation

$\bar{y}_b$ Hydrogen = 0.194, $S_b \sqrt{1 + 1/4}$ Hydrogen = 0.027

$\bar{y}_b$ Specific conductance = 57,500, $S_b \sqrt{1 + 1/4}$ = 6,930

t = Calculated average replicate t statistic for the monitor well compared to upgradient well MW-1.

tc = Critical value of t, from Tables 16 and 17 (overall alpha = 0.01, degrees of freedom (df) = 3).

tc Hydrogen = 8.061

tc Specific conductance = 7.285

Values for t (absolute value in the case of hydrogen) exceeding tc indicate concentrations in the well samples are statistically greater (or lesser in the case of hydrogen) than well MW-1 background.

TABLE 11

RESULTS OF THE AVERAGED REPLICATE t-TEST COMPARING BACKGROUND TOC AND POX DATA FROM THE UPGRADIENT WELL MW-1 WITH DATA COLLECTED DURING THE FIRST SEMIANNUAL SAMPLING SEWAGE TREATMENT LAGOONS MONITORING WELLS, HOLLOMAN AIR FORCE BASE, NEW MEXICO JANUARY 1990

	TOC (mg/l)			POX (mg/l as chloride)		
WELL	$\bar{y}_m$	$\bar{y}_m - \bar{y}_b$	t	$\bar{y}_m$ [a]	$\bar{y}_m - \bar{y}_b$	t
MW-1	1	-2	-0.333	0.005	-0.495	-0.495
S-2	5	2	0.333	0.005	-0.495	-0.495
MW-2	4	1	0.167	0.005	-0.495	-0.495
MW-3	8	5	0.833	0.005	-0.495	-0.495
MW-4	6	3	0.500	0.005	-0.495	-0.495
MW-5	5	2	0.333	0.005	-0.495	-0.495
MW-6	4	1	0.167	0.005	-0.495	-0.495
MW-7	3	0	0.000	0.005	-0.495	-0.495
MW-8	4	1	0.167	0.005	-0.495	-0.495
S-4	1	-2	-0.333	0.005	-0.495	-0.495

(a) Assumed value, one half detection limit of 0.010 mg/l as chloride.
$\bar{y}_m$ = Monitor well replicate average for January 1990 sampling results.
$\bar{y}_b$ = Well MW-1 background average, S_b = well MW-1 background standard deviation
$\bar{y}_b$ TOC = 3, $S_b \sqrt{1 + 1/4} = 6$
$\bar{y}_b$ POX = 0.5, $S_b \sqrt{1 + 1/4} = 1.0$
t = Calculated average replicate t statistic for the monitor well compared to upgradient well MW-1.
tc = Critical value of t, from Table 17 (overall alpha = 0.01, degrees of freedom (df) = 3) = 7.285.
Values for t exceeding tc indicate concentrations in the well samples are statistically greater than well MW-1 background.

TABLE 12

RESULTS OF THE AVERAGED REPLICATE t-TEST COMPARING BACKGROUND HYDROGEN (pH) AND SPECIFIC CONDUCTANCE DATA FROM THE UPGRADIENT WELL S-2 WITH DATA COLLECTED DURING THE FIRST SEMIANNUAL SAMPLING SEWAGE TREATMENT LAGOONS MONITORING WELLS, HOLLOMAN AIR FORCE BASE, NEW MEXICO JANUARY 1990

	HYDROGEN (μmol/l)			SPECIFIC CONDUCTANCE (μmhos/cm @ 25°C)		
WELL	$\bar{y}_m$	$\bar{y}_m - \bar{y}_b$	t	$\bar{y}_m$	$\bar{y}_m - \bar{y}_b$	t
MW-1	0.268	0.201	13.400	59,900	50,600	23.868
S-2	0.083	0.016	1.067	5,800	-3,500	-1.651
MW-2	0.065	-0.002	-0.133	5,500	-3,800	-1.792
MW-3	0.093	0.026	1.733	15,900	6,600	3.113
MW-4	0.183	0.116	7.733	12,200	2,900	1.368
MW-5	0.154	0.087	5.800	15,400	6,100	2.877
MW-6	0.133	0.066	4.400	94,800	85,500	40.330
MW-7	0.165	0.098	6.533	6,400	-2,900	-1.368
MW-8	0.107	0.040	2.667	9,800	500	0.236
S-4	0.096	0.029	1.933	64,300	55,000	25.943

$\bar{y}_m$ = Monitor well replicate average for January 1990 sampling results.
$\bar{y}_b$ = Well S-2 background average, S_b = well S-2 background standard deviation
  $\bar{y}_b$ Hydrogen = 0.067, $S_b \sqrt{1 + 1/4} = 0.015$
  $\bar{y}_b$ Specific conductance = 9,300, $S_b \sqrt{1 + 1/4} = 2120$
t = Calculated average replicate t statistic for the monitor well compared to upgradient well S-2.
tc = Critical value of t, from Tables 16 and 17 (overall alpha = 0.01, degrees of freedom (df) = 3).
  tc Hydrogen = 8.061
  tc Specific conductance = 7.285
Values for t (absolute value in the case of hydrogen) exceeding tc indicate concentrations in the well samples are statistically greater (or lesser in the case of hydrogen) than well S-2 background.

TABLE 13

RESULTS OF THE AVERAGED REPLICATE t-TEST COMPARING TOC AND POX DATA FROM THE UPGRADIENT WELL S-2 WITH DATA COLLECTED DURING THE FIRST SEMIANNUAL SAMPLING SEWAGE TREATMENT LAGOONS MONITORING WELLS, HOLLOMAN AIR FORCE BASE, NEW MEXICO JANUARY 1990

	TOC (mg/l)			POX (mg/l as chloride)		
WELL	$\bar{y}_m$	$\bar{y}_m - \bar{y}_b$	t	$\bar{y}_m$(a)	$\bar{y}_m - \bar{y}_b$	t
MW-1	1	-6	-6.00	0.005	-0.017	-0.607
S-2	5	-2	-2.00	0.005	-0.017	-0.607
MW-2	4	-3	-3.00	0.005	-0.017	-0.607
MW-3	8	1	1.000	0.005	-0.017	-0.607
MW-4	6	-1	-1.000	0.005	-0.017	-0.607
MW-5	5	-2	-2.000	0.005	-0.017	-0.607
MW-6	4	-3	-3.000	0.005	-0.017	-0.607
MW-7	3	-4	-4.000	0.005	-0.017	-0.607
MW-8	4	-3	-3.000	0.005	-0.017	-0.607
S-4	1	-6	-6.000	0.005	-0.017	-0.607

(a)Assumed value, one-half detection limit of 0.010 mg/l as chloride.
$\bar{y}_m$ = Monitor well replicate average for January 1990 sampling episode.
$\bar{y}_b$ = Well S-2 background average, S_b = well S-2 background standard deviation.
$\bar{y}_b$ TOC = 7, $S_b \sqrt{1 + 1/4} = 1$
$\bar{y}_b$ POX = 0.022, $S_b \sqrt{1 + 1/4} = 0.028$
t = Calculated average replicate t statistic for the monitor well compared to upgradient well S-2.
tc = Critical value of t, from Table 17 (overall alpha = 0.01, degrees of freedom (df) = 3) = 7.285.
Values for t exceeding tc indicate concentrations in the well samples are statistically greater than well S-2 background.

TABLE 14

RESULTS OF THE AVERAGED REPLICATE t-TEST COMPARING BACKGROUND HYDROGEN (pH) AND SPECIFIC CONDUCTANCE DATA FROM ALL UPGRADIENT WELLS WITH DATA COLLECTED DURING THE FIRST SEMIANNUAL SAMPLING SEWAGE TREATMENT LAGOONS MONITORING WELLS, HOLLOMAN AIR FORCE BASE, NEW MEXICO JANUARY 1990

	HYDROGEN (μmol/l)			SPECIFIC CONDUCTANCE (μmhos/cm @ 25°C)		
WELL	$\bar{y}_m$	$\bar{y}_m - \bar{y}_b$	t	$\bar{y}_m$	$\bar{y}_m - \bar{y}_b$	t
MW-1	0.268	0.138	1.865	59,900	26,500	0.957
S-2	0.083	-0.047	-0.635	5,800	-27,600	-0.996
MW-2	0.065	-0.065	-0.878	5,500	-27,900	-1.007
MW-3	0.093	-0.037	-0.500	15,900	-17,500	-0.632
MW-4	0.183	0.053	0.716	12,200	-21,200	-0.765
MW-5	0.154	0.024	0.324	15,400	-18,000	-0.650
MW-6	0.133	0.003	0.041	94,800	61,400	2.217
MW-7	0.165	0.035	0.473	6,400	-27,000	-0.975
MW-8	0.107	-0.023	-0.311	9,800	-23,600	-0.852
S-4	0.096	-0.034	-0.459	64,300	30,900	1.116

$\bar{y}_m$ = Monitor well replicate average for January 1990 sampling results.
$\bar{y}_b$ = All upgradient wells background average, S_b = All upgradient background standard deviation
$\bar{y}_b$ Hydrogen = 0.130, $S_b \sqrt{1 + 1/8}$ = 0.074
$\bar{y}_b$ Specific conductance = 33,400, $S_b \sqrt{1 + 1/8}$ = 27,700
t = Calculated average replicate t statistic for the monitor well compared to all upgradient wells.
tc = Critical value of t, from Tables 16 and 17 (overall alpha = 0.01, degrees of freedom (df) = 7).
tc Hydrogen = 5.547
tc Specific conductance = 5.111
Values for t (absolute value in the case of hydrogen) exceeding tc indicate concentrations in the well samples are statistically greater (or lesser in the case of hydrogen) than upgradient background.

TABLE 15

RESULTS OF THE AVERAGED REPLICATE t-TEST COMPARING TOC AND POX DATA FROM ALL UPGRADIENT WELLS WITH DATA COLLECTED DURING THE FIRST SEMIANNUAL SAMPLING SEWAGE TREATMENT LAGOONS MONITORING WELLS, HOLLOMAN AIR FORCE BASE, NEW MEXICO JANUARY 1990

	TOC (mg/l)			POX (mg/l as chloride)		
WELL	$\bar{y}_m$	$\bar{y}_m - \bar{y}_b$	t	$\bar{y}_m$(a)	$\bar{y}_m - \bar{y}_b$	t
MW-1	1	-4	-1.00	0.005	-0.295	-0.421
S-2	5	0	0.000	0.005	-0.295	-0.421
MW-2	4	-1	-0.250	0.005	-0.295	-0.421
MW-3	8	3	0.750	0.005	-0.295	-0.421
MW-4	6	1	0.250	0.005	-0.295	-0.421
MW-5	5	0	0.000	0.005	-0.295	-0.421
MW-6	4	-1	-0.250	0.005	-0.295	-0.421
MW-7	3	-2	-0.500	0.005	-0.295	-0.421
MW-8	4	-1	-0.250	0.005	-0.295	-0.421
S-4	1	-4	-1.000	0.005	-0.295	-0.421

(a)Assumed value, one-half detection limit of 0.010 mg/l as chloride.

$\bar{y}_m$ = Monitor well replicate average for January 1990 sampling episode.

$\bar{y}_b$ = All upgradient wells background average, S_b = All upgradient wells background standard deviation.

$\bar{y}_b$ TOC = 5, $S_b \sqrt{1 + 1/8} = 4$

$\bar{y}_b$ POX = 0.3, $S_b \sqrt{1 + 1/8} = 0.7$

t = Calculated average replicate t statistic for the monitor well compared to upgradient well S-2.

tc = Critical value of t, from Table 17 (overall alpha = 0.01, degrees of freedom (df) = 7) = 5.111.

Values for t exceeding tc indicate concentrations in the well samples are statistically greater than all upgradient wells background.

TABLE 16

ONE TAILED CRITICAL (t_C) VALUES WHICH CONTROL THE OVERALL SIGNIFICANCE LEVEL AT ONE PERCENT

TOTAL NO. OF WELLS	DEGREES OF FREEDOM ASSOCIATED WITH THE AVERAGED REPLICATE TEST STATISTIC								
	3	7	11	15	19	23	27	31	35
4	6.297	4.543	4.065	3.841	3.712	3.628	3.568	3.524	3.490
5	6.534	4.609	4.175	3.939	3.803	3.714	3.651	3.604	3.569
6	6.729	4.793	4.265	4.019	3.876	3.783	3.718	3.669	3.569
7	6.896	4.889	4.342	4.086	3.939	3.842	3.774	3.724	3.388
8	7.041	4.972	4.408	4.145	3.992	3.893	3.823	4.771	3.490
9	7.169	5.045	4.466	4.196	3.039	3.937	3.865	3.812	3.569
10	7.285	5.111	4.518	4.242	4.082	3.977	3.904	3.849	3.632
11	7.390	5.171	4.566	4.283	4.120	4.013	3.938	3.882	3.685
12	7.487	5.225	4.609	4.321	4.154	4.046	3.969	3.912	3.731
13	7.576	5.276	4.648	4.356	4.186	4.076	3.998	3.940	3.771
14	7.657	5.322	4.685	4.388	4.216	4.103	4.024	3.966	3.807
15	7.736	5.366	4.719	4.418	4.243	4.129	4.049	3.989	3.839

Source: RCRA Ground Water Monitoring Technical Enformcement Guidance Document (TEGD), September 1986, National Water Well Association, Dublin, Ohio.

TABLE 17

TWO TAILED CRITICAL (t_C) VALUES WHICH CONTROL THE OVERALL SIGNIFICANCE LEVEL AT ONE PERCENT

TOTAL NO. OF WELLS	DEGREES OF FREEDOM ASSOCIATED WITH THE AVERAGED REPLICATE TEST STATISTIC								
	3	7	11	15	19	23	27	31	35
4	7.041	4.972	4.408	4.145	3.992	3.893	3.823	3.771	3.731
5	7.285	5.111	4.518	4.242	4.154	4.046	3.969	3.912	3.869
6	7.487	5.225	4.609	4.321	4.154	4.046	3.969	3.912	3.869
7	7.659	5.322	4.685	4.388	4.216	4.103	4.024	3.966	3.920
8	7.808	5.406	4.751	4.446	4.269	4.153	4.072	4.012	3.965
9	7.941	5.481	4.810	4.496	4.315	4.197	4.114	4.052	4.004
10	8.061	5.547	4.862	4.542	4.357	4.236	4.151	4.088	4.039
11	8.169	5.608	4.909	4.583	4.394	4.271	4.185	4.120	4.071
12	8.269	5.663	4.952	4.621	4.429	4.304	4.215	4.150	4.100
13	8.361	5.714	4.992	4.655	4.460	4.333	4.244	4.177	4.126
14	8.446	5.761	5.029	4.687	4.489	4.360	4.270	4.202	4.150
15	8.525	5.805	5.063	4.717	4.516	4.386	4.294	4.226	4.173

Source: RCRA Ground Water Monitoring Technical Enformcement Guidance Document (TEGD), September 1986, National Water Well Association, Dublin, Ohio.

TABLE 18

GROUND WATER ELEVATIONS
WASTE WATER TREATMENT
LAGOONS MONITORING WELLS,
HOLLOMAN AIR FORCE BASE, NEW MEXICO
AUGUST 1989
(RADIAN, 1989)

MONITOR WELL	TOP OF CASING ELEVATION (FAMSL)	DEPTH TO STATIC WATER LEVEL[a] (FEET)	GROUND WATER ELEVATION (FAMSL)
MW-1	4053.42	11.34	4042.08
S-2	4040.56	11.65	4028.91
MW-2	4039.78	7.61	4032.17
MW-3	4037.38	10.38	4027.00
MW-4	4030.30	8.71	4021.59
MW-5	4039.30	7.30	4032.00
MW-6	4031.21	7.97	4023.24
MW-7	4039.88	7.63	4032.25
MW-8	4040.50	8.10	4032.40
S-4	4034.46	10.12	4024.34

(a) Measurement taken at mark point on well casing.

TABLE 19

GROUND WATER ELEVATIONS
WASTE WATER TREATMENT
LAGOONS MONITORING WELLS,
HOLLOMAN AIR FORCE BASE, NEW MEXICO
SEPTEMBER 1989

MONITOR WELL	TOP OF CASING ELEVATION (FAMSL)[a]	DEPTH TO GROUND WATER[b] (FEET)	GROUND WATER ELEVATION (FAMSL)
MW-1	4053.42	10.64	4042.78
S-2	4040.56	9.83	4030.73
MW-2	4039.78	5.19	4034.59
MW-3	4037.38	8.44	4028.94
MW-4	4030.30	5.44	4024.86
MW-5	4039.30	5.23	4034.07
MW-6	4031.21	6.27	4024.94
MW-7	4039.88	6.10	4033.78
MW-8	4040.50	5.73	4034.77
S-4	4034.46	8.85	4025.61

[a] Radian, 1989.
[b] Reference from top of casing. Measured on September 25, 1989.

TABLE 20

GROUND WATER ELEVATIONS
WASTE WATER TREATMENT
LAGOONS MONITORING WELLS,
HOLLOMAN AIR FORCE BASE, NEW MEXICO
NOVEMBER 1989

MONITOR WELL	TOP OF[a] CASING ELEVATION (FAMSL)	DEPTH TO[b] GROUND WATER (FEET)	GROUND WATER ELEVATION (FAMSL)
MW-1	4053.42	11.24	4042.18
S-2	4040.56	9.47	4031.09
MW-2	4039.78	6.04	4033.74
MW-3	4037.38	9.21	4028.17
MW-4	4030.30	6.41	4023.89
MW-5	4039.30	6.04	4033.26
MW-6	4031.21	8.13	4023.08
MW-7	4039.88	6.45	4033.43
MW-8	4040.50	6.95	4033.55
S-4	4034.46	9.52	4024.94

(a)Radian, 1989.
(b)Reference from top of casing. Measured on November 5, 1989.

TABLE 21

**GROUND WATER ELEVATIONS
WASTE WATER TREATMENT
LAGOONS MONITORING WELLS,
HOLLOMAN AIR FORCE BASE, NEW MEXICO
DECEMBER 1989**

MONITOR WELL	TOP OF[a] CASING ELEVATION (FAMSL)	DEPTH TO[b] GROUND WATER (FEET)	GROUND WATER ELEVATION (FAMSL)
MW-1	4053.42	11.44	4041.98
S-2	4040.56	9.20	4031.36
MW-2	4039.78	5.33	4034.45
MW-3	4037.38	8.84	4028.54
MW-4	4030.30	6.23	4024.07
MW-5	4039.30	5.48	4033.82
MW-6	4031.21	8.32	4022.89
MW-7	4039.88	6.01	4033.87
MW-8	4040.50	6.41	4034.09
S-4	4034.46	9.55	4024.91

[a]Radian,1989.
[b]Reference from top of casing. Measured on December 10, 1989.

TABLE 22

GROUND WATER ELEVATIONS WASTE WATER TREATMENT LAGOONS MONITORING WELLS, HOLLOMAN AIR FORCE BASE, NEW MEXICO JANUARY 1990

MONITOR WELL	TOP OF[a] CASING ELEVATION (FAMSL)	DEPTH TO[b] GROUND WATER (FEET)	GROUND WATER ELEVATION
MW-1	4053.42	11.24	4042.18
S-2	4040.56	9.06	4031.50
MW-2	4039.78	5.03	4034.75
MW-3	4037.38	8.48	4028.90
MW-4	4030.30	5.53	4024.77
MW-5	4039.30	5.21	4034.09
MW-6	4031.21	7.36	4023.85
MW-7	4039.88	5.83	4034.05
MW-8	4040.50	5.92	4034.58
S-4	4034.46	9.19	4025.27

[a]Radian, 1989.
[b]Reference from top of casing. Measured on January 15, 1990.

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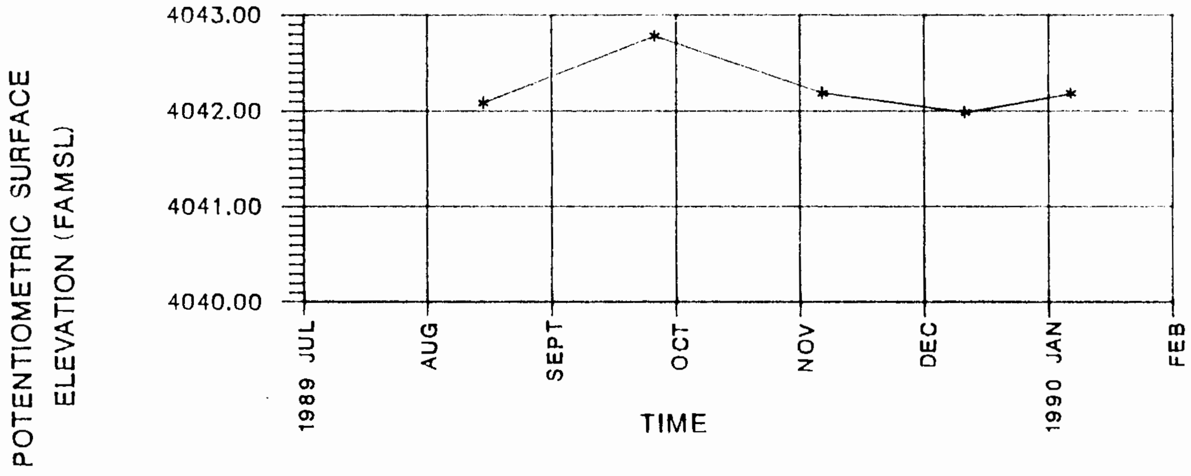
MONITOR WELL MW-1



MONITOR WELL S-2

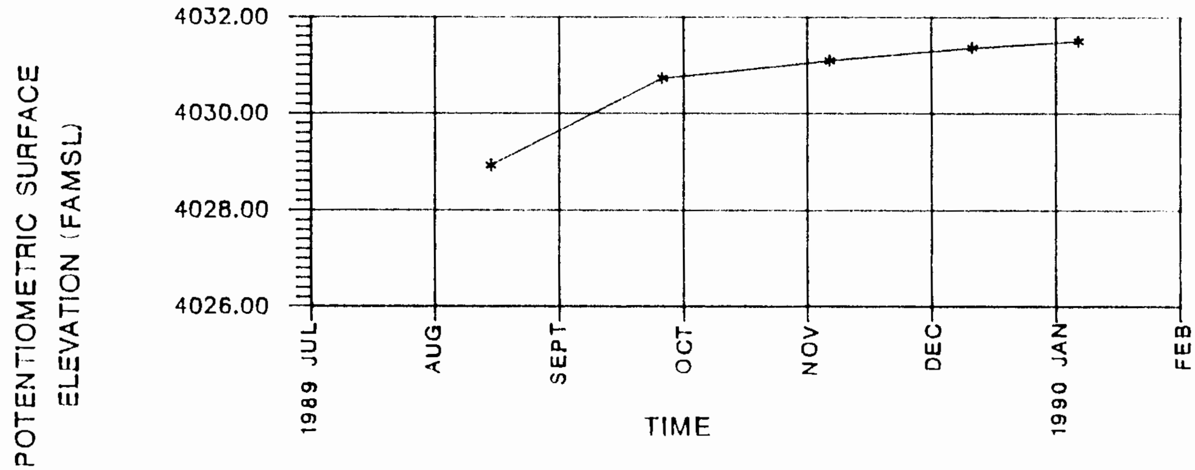


FIGURE 1

1 OF 5

HYDROGRAPHS OF
MONITOR WELLS AT
WASTEWATER TREATMENT LAGOONS
HOLLOMAN AIR FORCE BASE
ALAMOGORDO, NEW MEXICO

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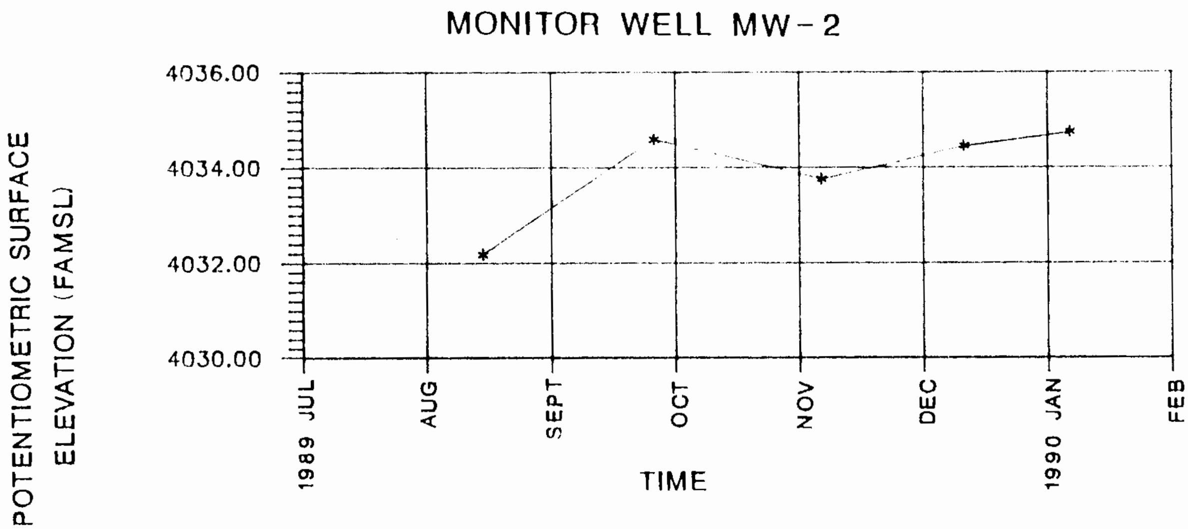

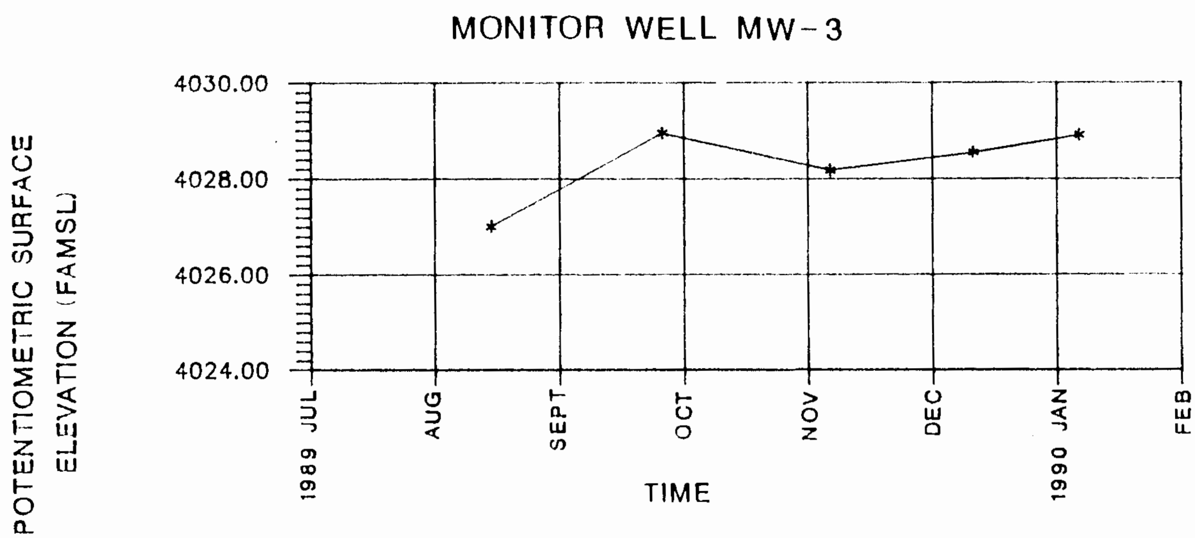

FIGURE 1

2 OF 5

HYDROGRAPHS OF
MONITOR WELLS AT
WASTEWATER TREATMENT LAGOONS
HOLLOMAN AIR FORCE BASE
ALAMOGORDO, NEW MEXICO

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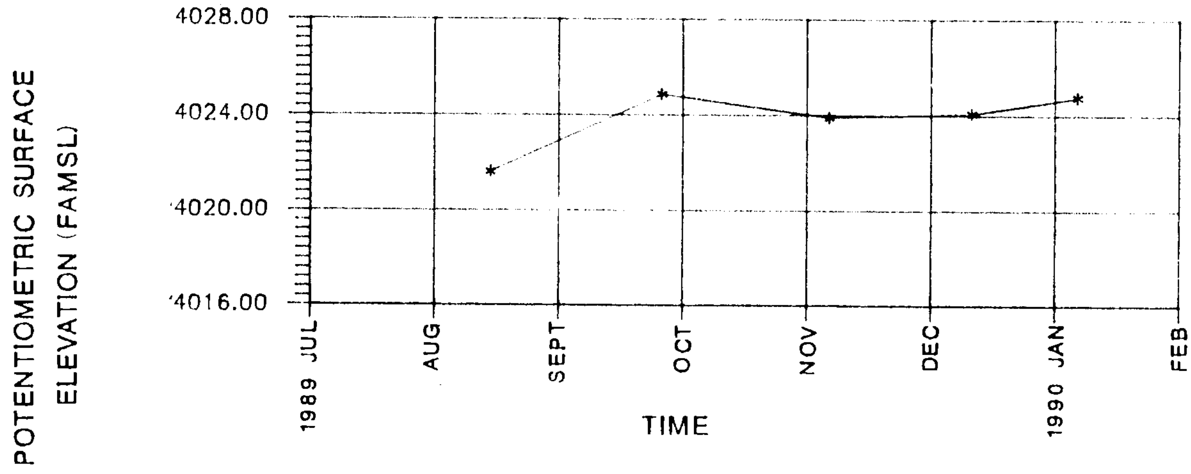
MONITOR WELL MW-4



MONITOR WELL MW-5

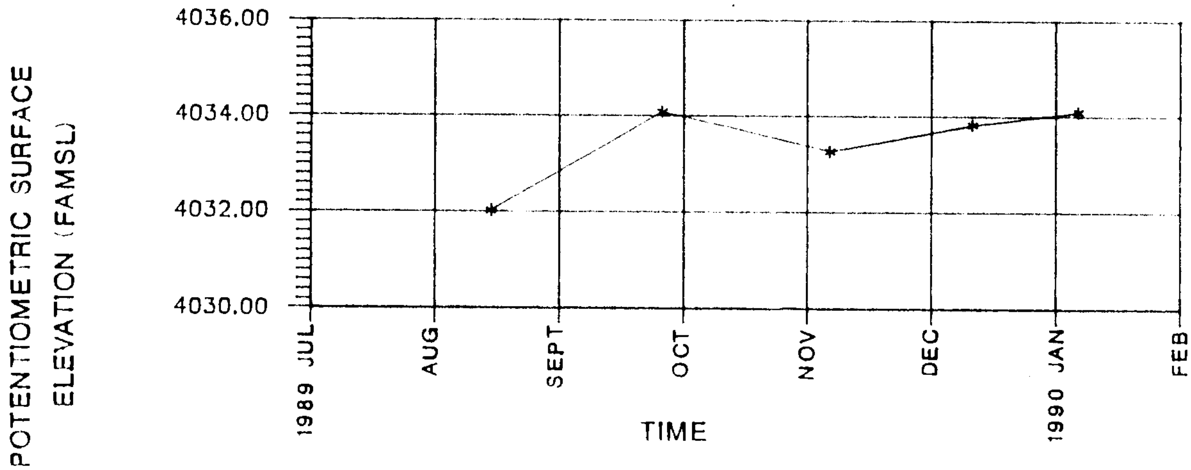


FIGURE 1

3 OF 5

HYDROGRAPHS OF
MONITOR WELLS AT
WASTEWATER TREATMENT LAGOONS
HOLLOMAN AIR FORCE BASE
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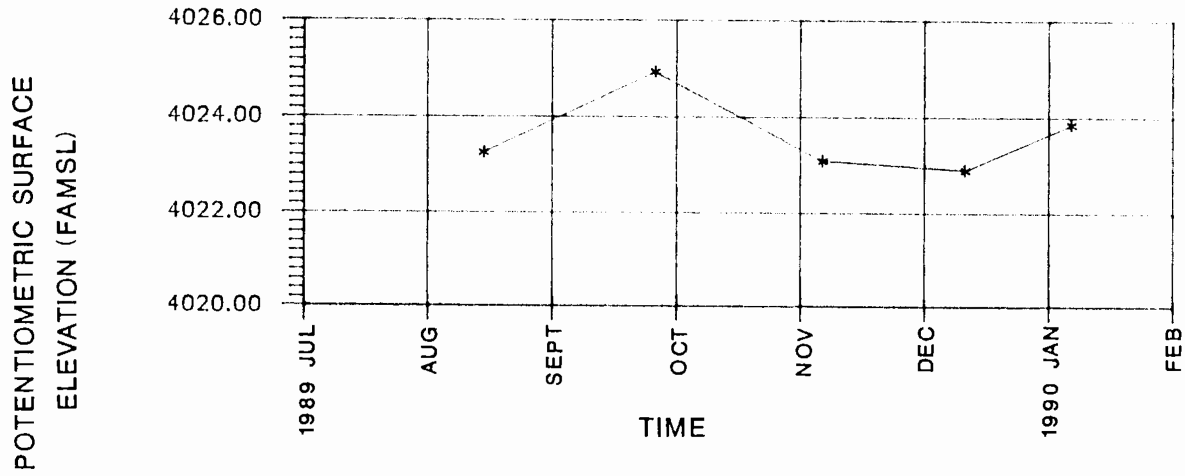
MONITOR WELL MW-6



MONITOR WELL MW-7

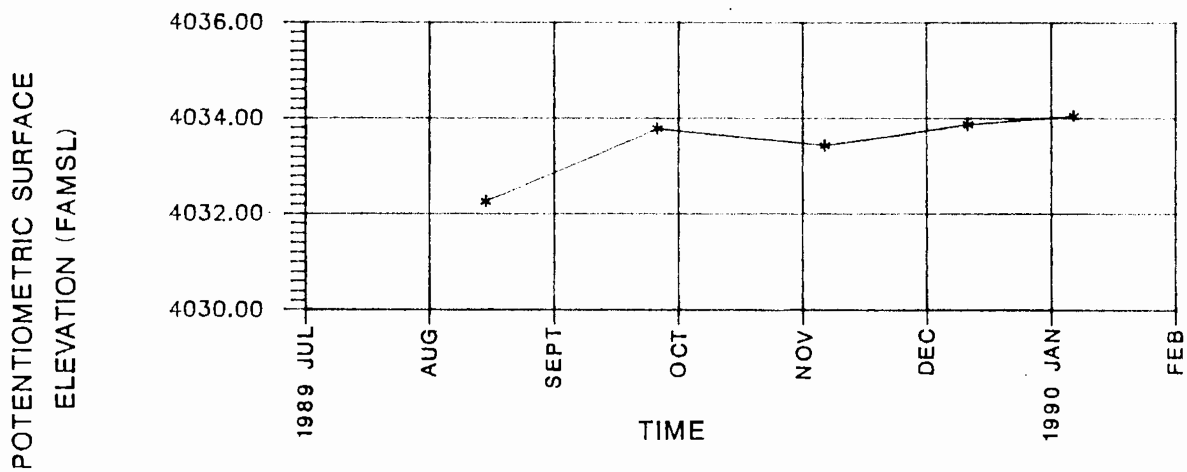


FIGURE 1

4 OF 5

HYDROGRAPHS OF
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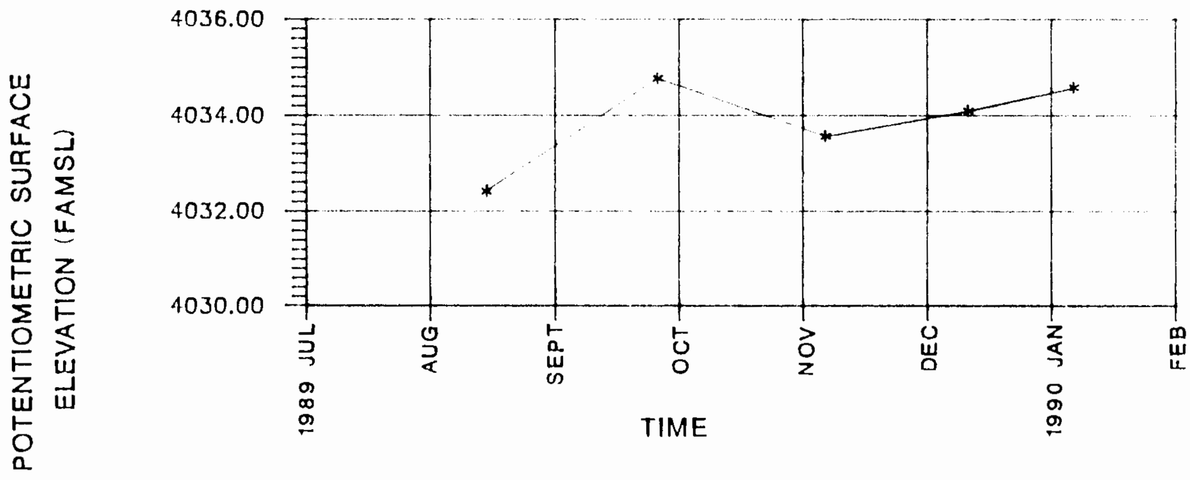
MONITOR WELL MW-8



MONITOR WELL S-4

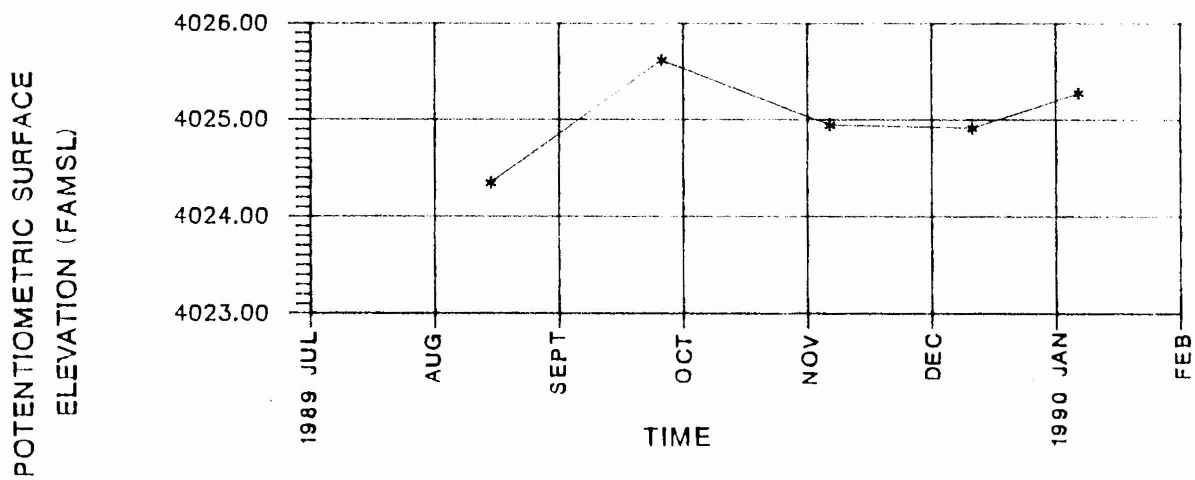


FIGURE 1

5 OF 5

HYDROGRAPHS OF
MONITOR WELLS AT
WASTEWATER TREATMENT LAGOONS
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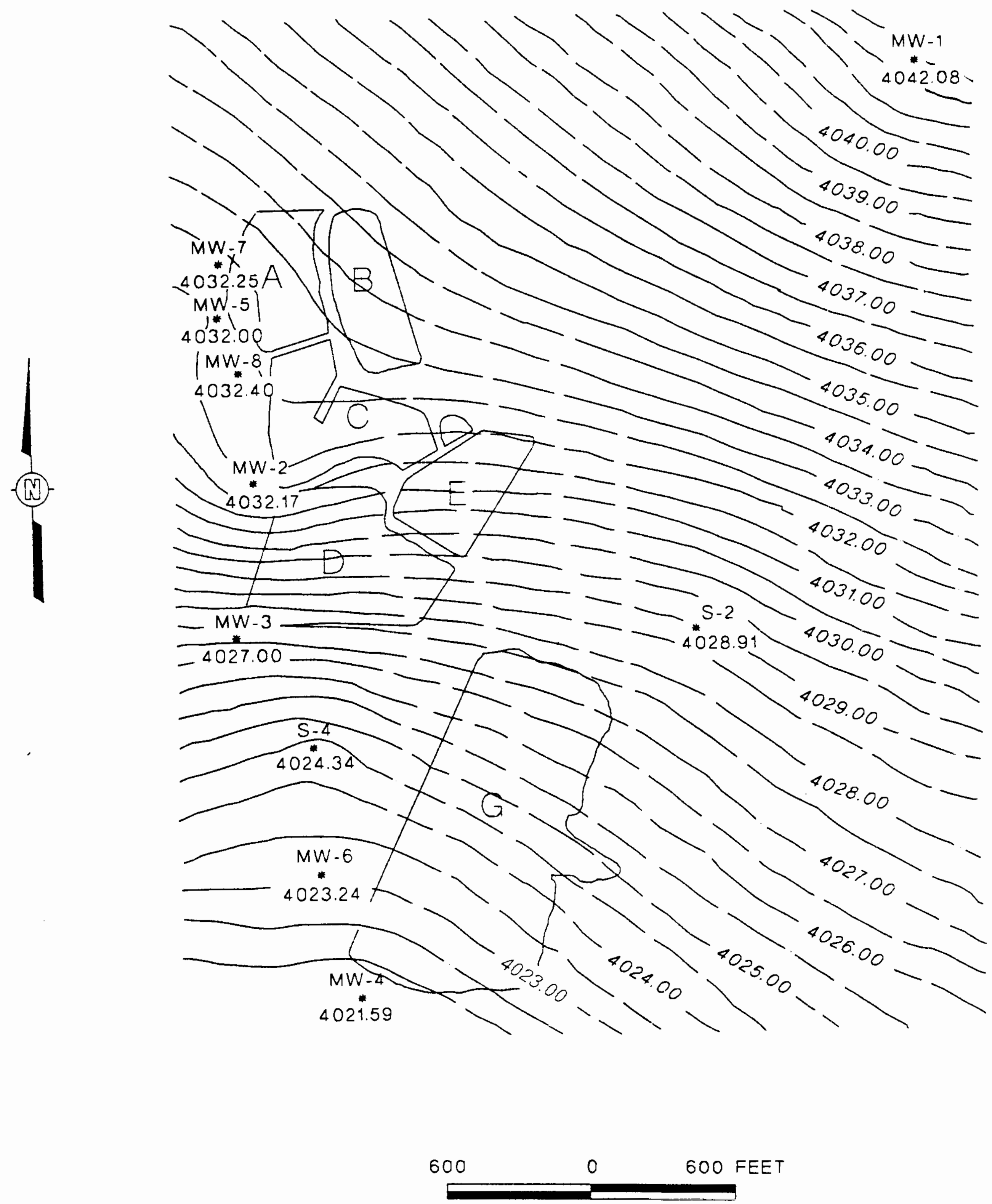

LEGEND

MW-1 WELL NUMBER

* WELL LOCATION

4042.08 GROUND WATER POTENTIOMETRIC SURFACE ELEVATION (FAMSL)

— 4026.00 — GROUND WATER SURFACE CONTOUR (FAMSL)

CONTOUR INTERVAL = 0.5

FIGURE 2

AUGUST 14 and 15, 1989
GROUND WATER POTENTIOMETRIC MAP
WASTE WATER TREATMENT LAGOONS
HOLLOMAN AIR FORCE BASE
ALAMOGORDO, NEW MEXICO

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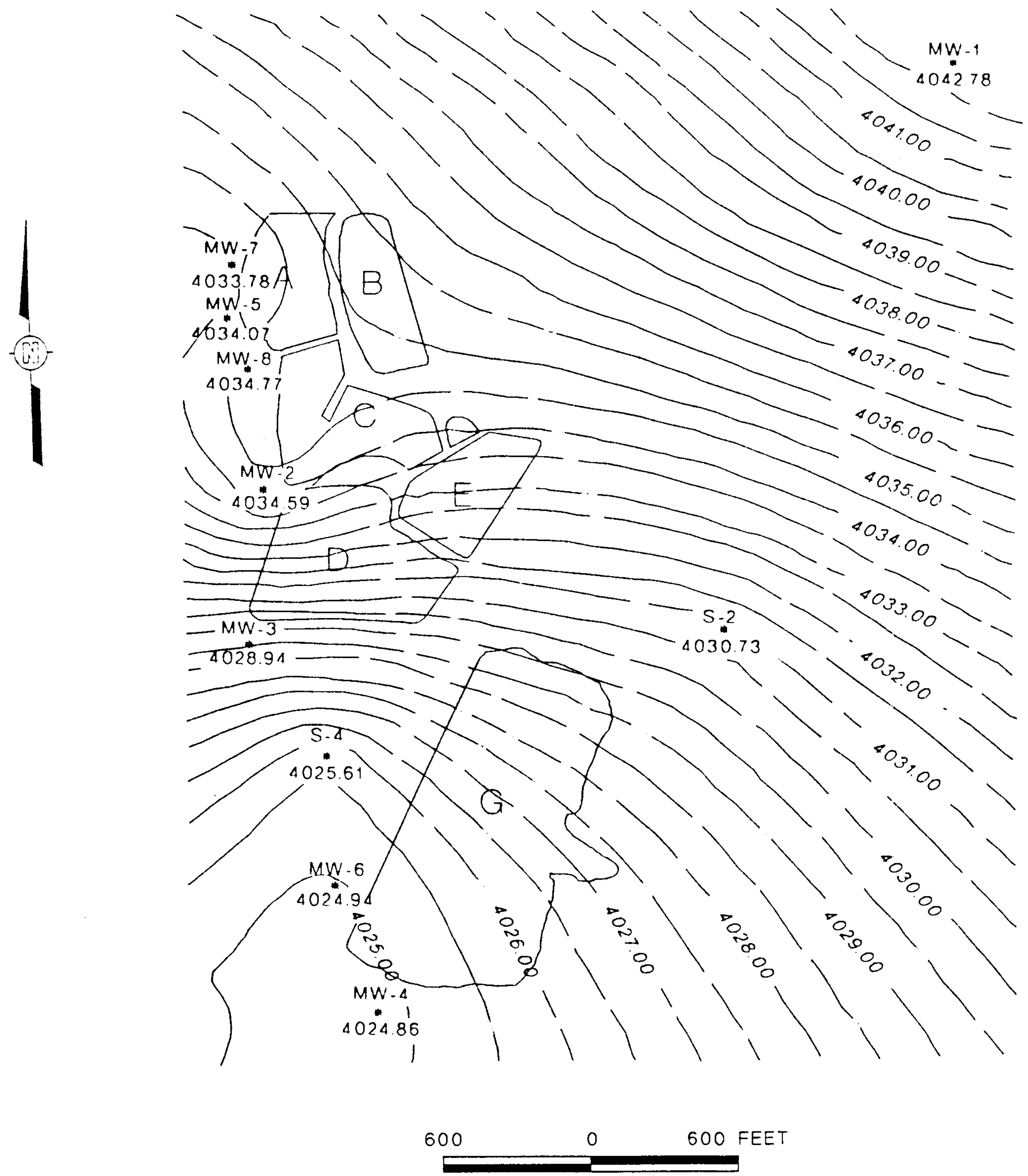

LEGEND

MW-1	WELL NUMBER
*	WELL LOCATION
4042.78	GROUND WATER POTENTIOMETRIC SURFACE ELEVATION (FAMSL)
— 4026.00 —	GROUND WATER SURFACE CONTOUR (FAMSL)
	CONTOUR INTERVAL = 0.5

FIGURE 3

SEPTEMBER 25, 1989
GROUND WATER POTENTIOMETRIC MAP
WASTE WATER TREATMENT LAGOONS
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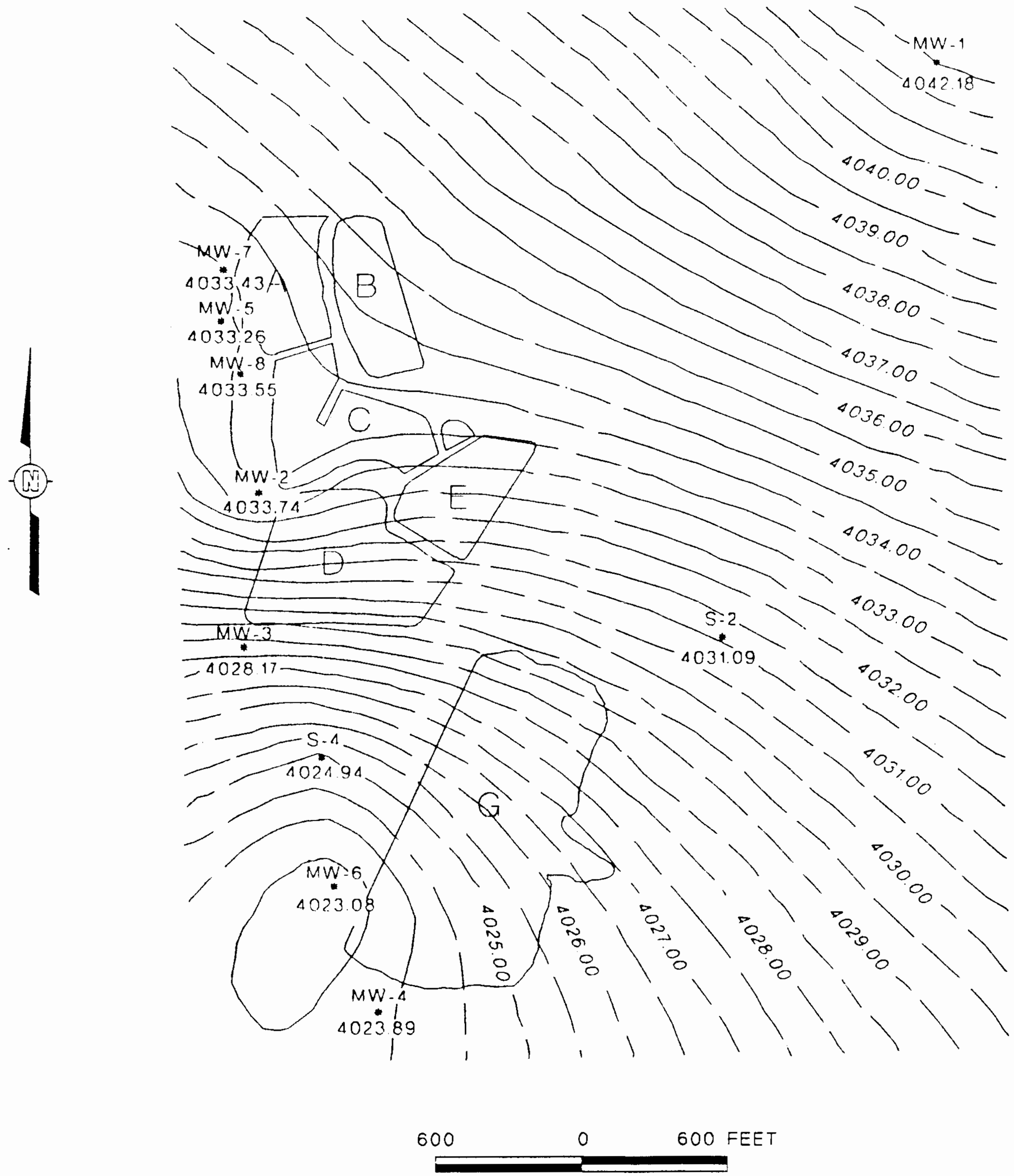

LEGEND

MW-1	WELL NUMBER
*	WELL LOCATION
4042.18	GROUND WATER POTENTIOMETRIC SURFACE ELEVATION (FAMSL)
— 4026.00 —	GROUND WATER SURFACE CONTOUR (FAMSL)
	CONTOUR INTERVAL = 0.5

FIGURE 4

NOVEMBER 5, 1989
GROUND WATER POTENTIOMETRIC MAP
WASTE WATER TREATMENT LAGOONS
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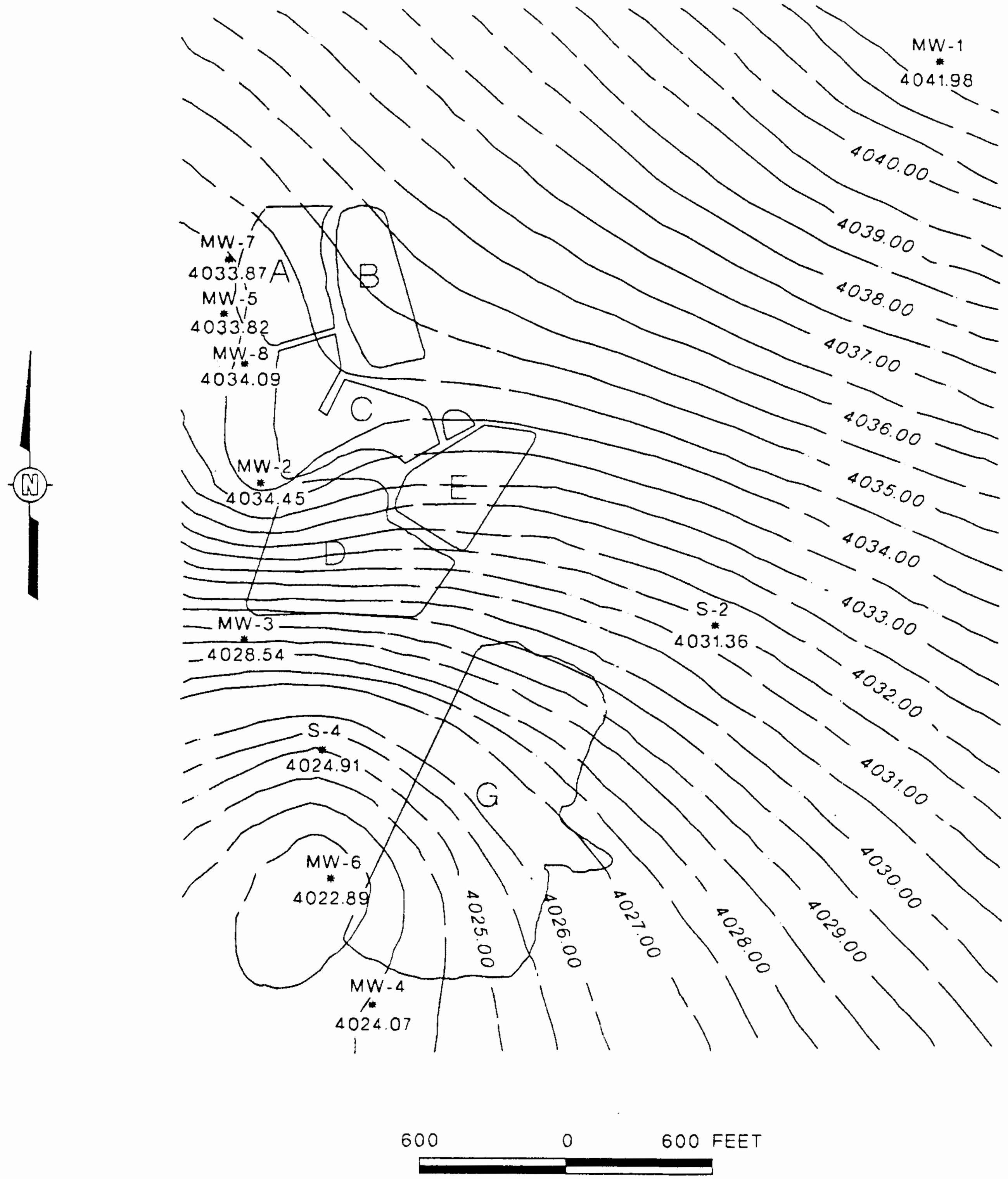

LEGEND

MW-1	WELL NUMBER
*	WELL LOCATION
4041.98	GROUND WATER POTENTIOMETRIC SURFACE ELEVATION (FAMSL)
— 4026.00 —	GROUND WATER SURFACE CONTOUR (FAMSL)
	CONTOUR INTERVAL = 0.5

FIGURE 5

DECEMBER 10, 1989
GROUND WATER POTENTIOMETRIC MAP
WASTE WATER TREATMENT LAGOONS
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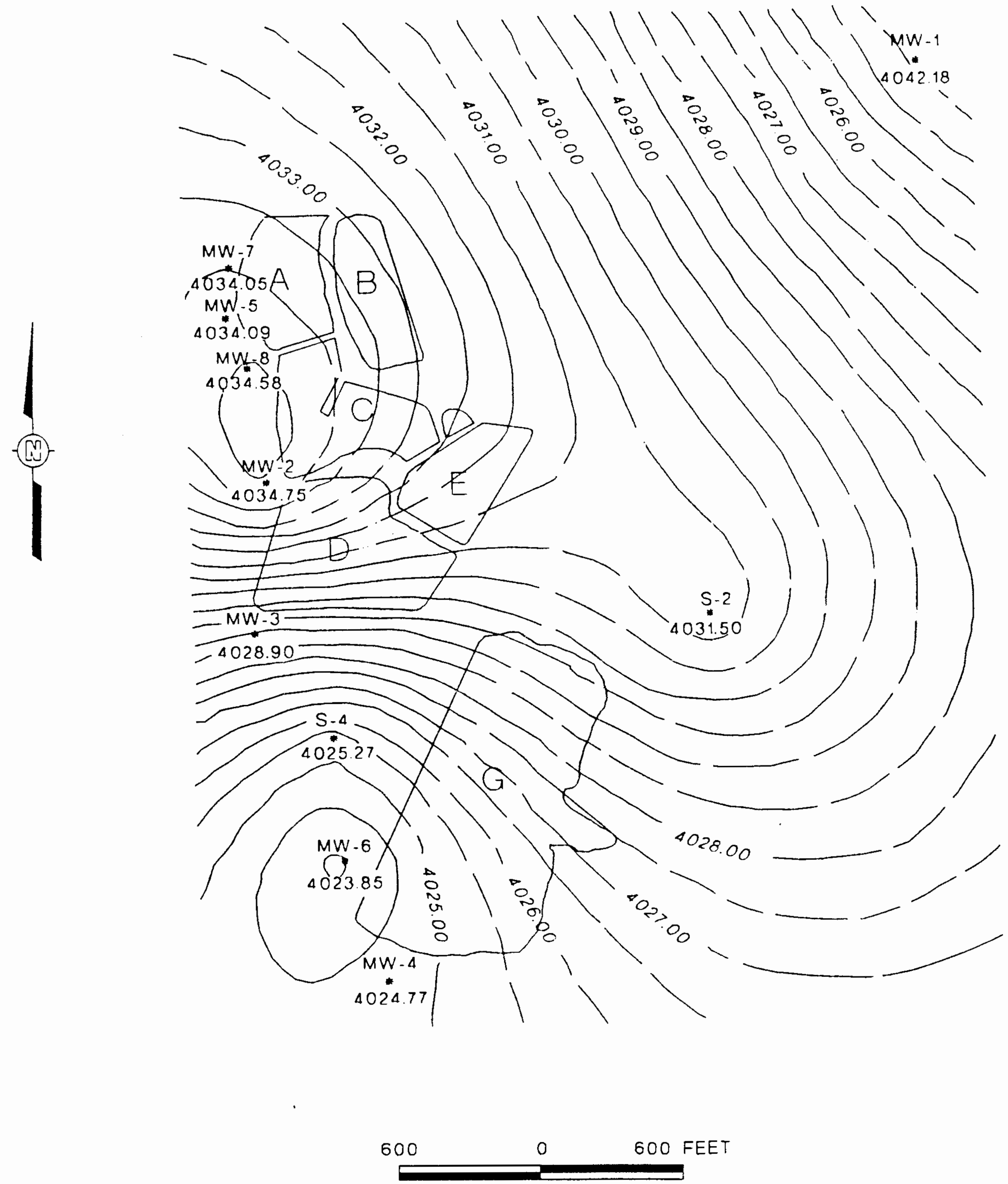

LEGEND

MW-1	WELL NUMBER
*	WELL LOCATION
4042.18	GROUND WATER POTENTIOMETRIC SURFACE ELEVATION (FAMSL)
— 4026.00 —	GROUND WATER SURFACE CONTOUR (FAMSL)
	CONTOUR INTERVAL = 0.5

FIGURE 6

JANUARY 15, 1990
GROUND WATER POTENTIOMETRIC MAP
WASTE WATER TREATMENT LAGOONS
HOLLOMAN AIR FORCE BASE
ALAMOGORDO, NEW MEXICO

PREPARED FOR

CORPS OF ENGINEERS, OMAHA DISTRICT

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"Do Not Scale This Drawing"