AN INVESTIGATION OF GROUNDWATER CONTAMINATION FROM AN ONSITE SEWAGE DISPOSAL SYSTEM (OSDS) AT A SINGLE FAMILY HOME IN FLORIDA

Phase 2 Report

To

SDA

The Soap and Detergent Association
475 Park Avenue South
New York, New York 10016

April, 1993

AYRES
ASSOCIATES

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By

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I. INTRODUCTION

The Soap and Detergent Association (SDA) has retained Ayres Associates to investigate the occurrence of certain chemical constituents in groundwater below and downgradient of Onsite Sewage Disposal Systems (OSDS) in Florida. The purpose of the investigation was to define the contaminant plume of such a system and then to determine if key constituents of certain household cleaning products are present in the plume and if so, to what extent. This report reviews work completed in the preliminary phase of the investigation and the determination of the preliminary contaminant plume, then describes work conducted during the second phase of the project.

1.1 Background

Ayres Associates conducted a study of the impacts of OSDS on groundwater quality as part of the Florida Onsite Sewage Disposal System Research Project from 1987 to 1990. An individual home in St Johns County was chosen from this prior study as a potential site for further investigation of groundwater quality impacts for the Soap and Detergent Association (SDA). The investigation was specifically focused on determining the plume of impacted groundwater and subsequent evaluation of groundwater samples for key parameters of interest to SDA.

The preliminary phase of this project was completed in March, 1991. The objective of the first phase of the project was to attempt to delineate the effluent plume with conservative parameters such as chloride, conductivity, or nitrate-nitrogen, then develop a plan for further investigation incorporating additional parameters.

Water use was metered to estimate wastewater loading to the OSDS drainfield and samples of septic tank effluent (STE) were obtained to characterize the quality of the wastewater discharged to the OSDS infiltration system. Three groundwater piezometers were installed to determine groundwater flow direction. A stainless steel probe system, originally designed for soil gas monitoring in the unsaturated zone, was used to obtain groundwater samples without the time and expense of installing permanent groundwater monitoring wells. Forty-seven groundwater samples were collected and analyzed in the field for chloride, nitrate-nitrogen, and conductivity. Four groundwater monitoring wells were installed and groundwater samples for various water quality parameters were obtained to compare the results with groundwater samples obtained with the stainless steel probe.

The results of the preliminary investigation indicated:

1) Groundwater flow direction was south-southwest.

2) Wastewater flow was estimated to be 168 gpd.

3) Surfactant concentrations in septic tank effluent as measured by MBAS were 2 to 3 times higher than those measured previously and significantly higher than any household samples collected as part of the Florida OSDS Research Project. Additional sampling of STE was recommended to determine the accuracy of the MBAS sampling and analysis.

4) The field analyses of conservative groundwater quality parameters indicated two areas of potential impact. One area was upgradient (east) of the infiltration system and one area was downgradient (southwest). The cause of the impacted area east of the system was not determined. Effluent impact on groundwater in the area downgradient of the OSDS did not extend further than approximately 10 to 15 feet from the system indicating either an extremely slow rate of horizontal groundwater movement, which was contradictory to those groundwater velocities calculated during the previous OSDS study, or that vertical movement of groundwater may have carried contaminants to a deeper level.

Based on these results, further work was recommended that included the collection of additional water use data and STE quality data, the installation of nested sets of shallow and deep groundwater monitoring wells, and the installation of a more permanent downgradient miniature monitoring well network, collection and laboratory analysis of groundwater samples from the miniature wells, and the preparation of a data summary report. Ayres Associates was contracted to conduct the additional work in May, 1992. The work was completed in January, 1993.

1.2 Objectives

The objectives of the second phase of the SDA project was to delineate the contaminate plume at the OSDS of a single family home in St. Johns County, Florida and evaluate the fate and transport of key water quality parameters of interest to the SDA.

1.3 Scope of Work

In order to accomplish these objectives , Ayres Associates proposed the following scope of work:

- Determine household wastewater quantity and quality.
- Install three nested sets of groundwater monitoring wells to determine aquifer thickness and vertical groundwater gradient.
- Utilize the "direct push" sampling technology and field measurement of conservative parameters to outline the location of groundwater impacted by the OSDS infiltration system.
- Determine horizontal and vertical extent of various effluent parameters, including MBAS, to groundwater.
- Prepare a final report describing results of the study and develop the scope of any further investigations at the site.

II. SITE CHARACTERISTICS

2.1 Residence Characteristics

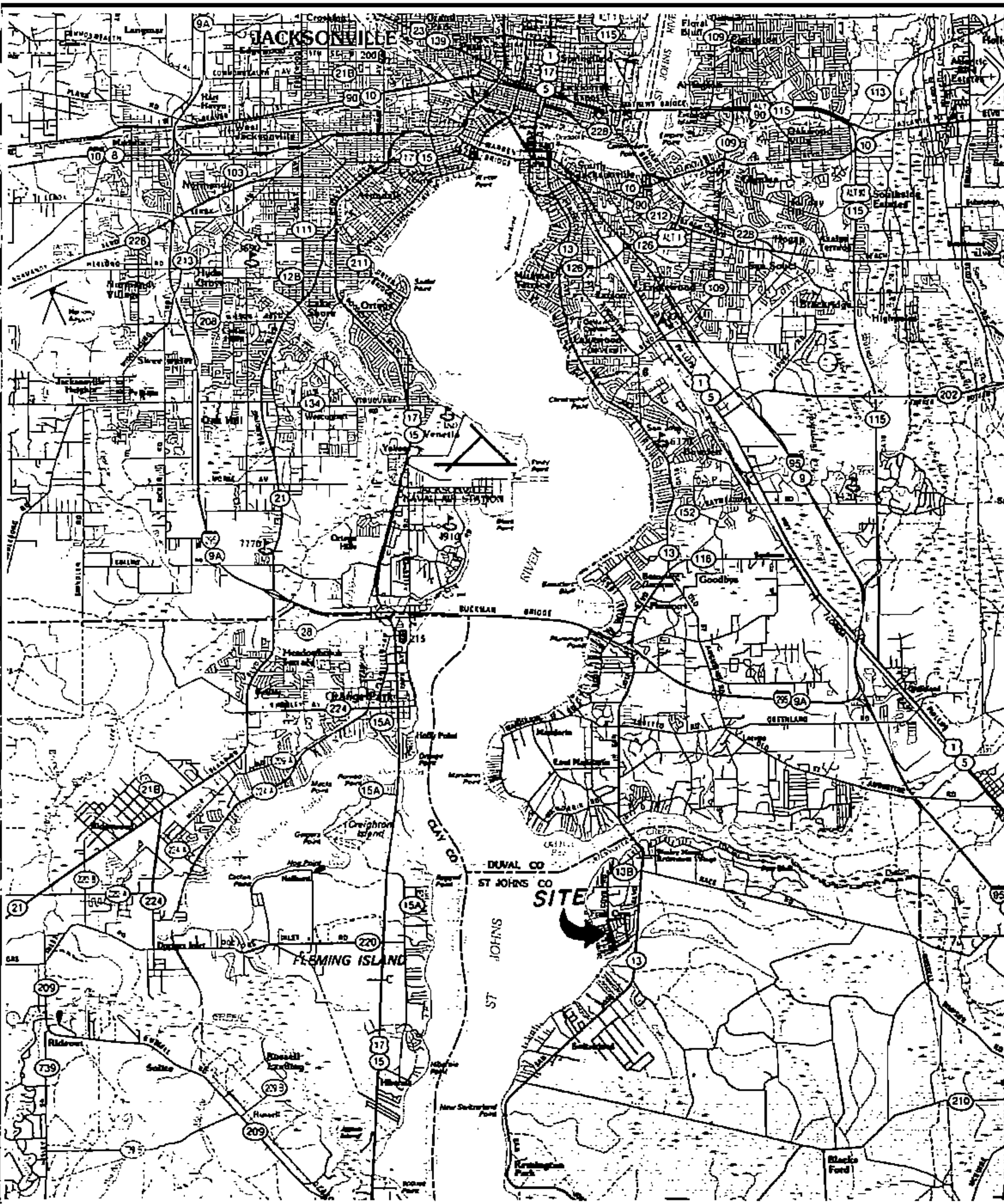
The residence depicted in this investigation is located in St. Johns County, Florida, immediately south of the city of Jacksonville. The home is in a subdivision of about 200 homes located about one-half mile east of the St. Johns River. A general location map of the site is shown in Figure 2.1.1.

The home is a three bedroom, two bathroom home constructed in 1976. It is served by an OSDS consisting of a 900 gallon septic tank and 210 ft^2 infiltration system composed of three, two-foot wide gravel-filled trenches. Further characteristics of the study residence are listed in Table 2.1.1. Figure 2.1.2 is a site plan which shows a plan view of the OSDS in the homes backyard.

2.2 Physiography and Climate

The site is located in the physiographic province referred to as the Coastal Lowlands. The topography of the lowlands is controlled by a series of marine terraces which were formed during Pleistocene time. Elevations at the site range from 10 to 15 feet above mean sea level (MSL). Surface drainage in the area is primarily through the St Johns River and its tributaries. The majority of surface runoff at the site is directed south-southeastward towards a local topographic depression which is undeveloped. Drainage ultimately enters the St Johns River via a creek just south of the site. The St. Johns River generally flows northward to the Jacksonville area where it turns sharply toward the east and empties into the Atlantic Ocean.

The climate of St. Johns County is subtropical and is characterized by warm, humid summers and mild, dry winters with occasional frost from November to February. Annual average rainfall is approximately 54 inches. Rainfall is seasonal with the majority falling during the months of June through September. During these months, the rain usually falls from localized heavy showers of short duration.



AYRES ASSOCIATES

GENERAL LOCATION MAP
St. Johns County Subdivision
Fruit Cove, St. Johns County, Florida
Job No. 4155.00
Figure 2.1.1

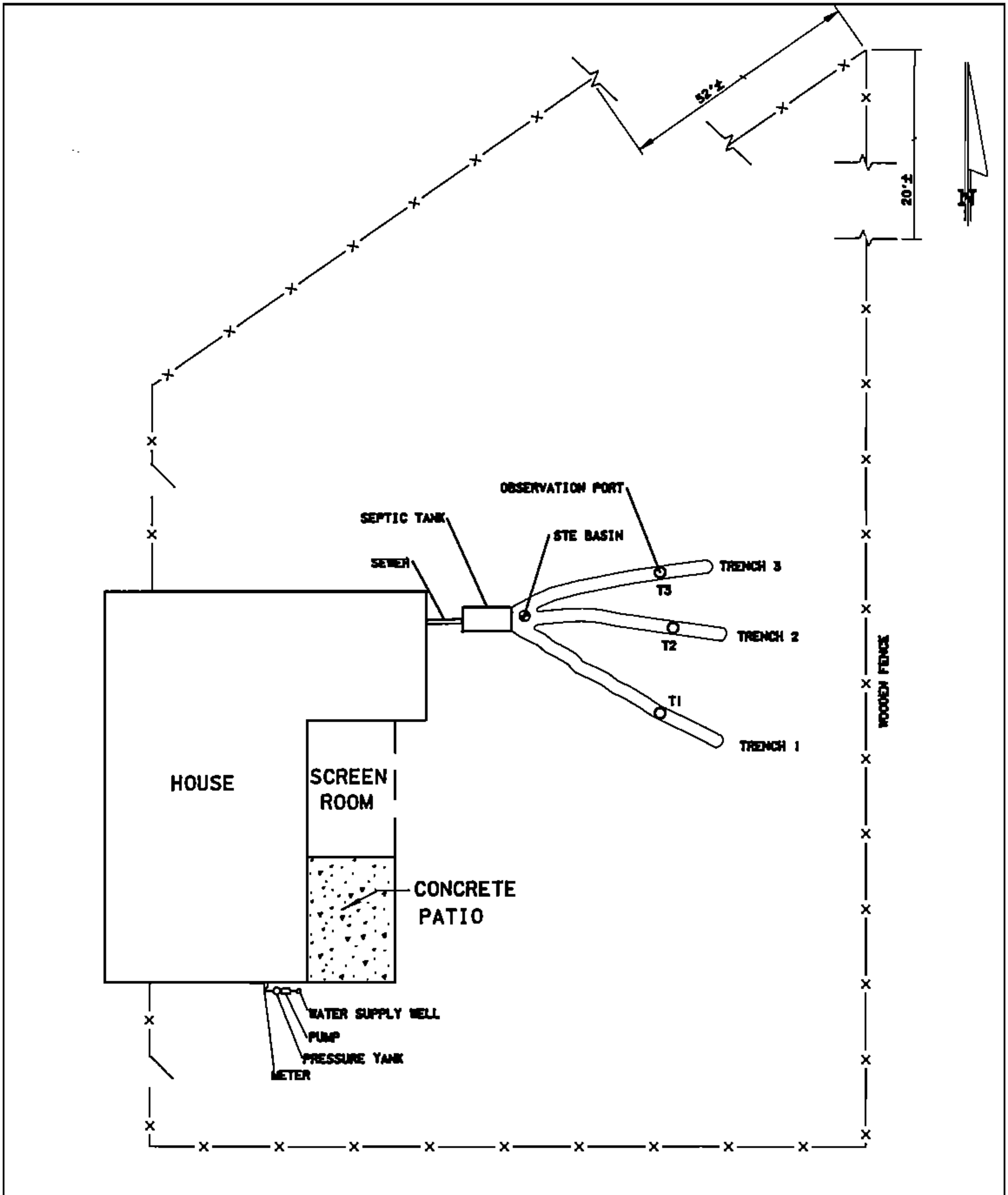
Table 2.1.1. Characteristics of Individual Monitoring Site[1].

Number of Residents	4
Adults	2
Children	2 (ages 7and 11)
Lot Size	0.47 acres
Age of Home	17 years
Occupancy	11 years
Number of Bedrooms	3
Number of Bathrooms	2
Dishwasher	Yes
Clothes Washer	Yes
Garbage Disposal	No
Water Softener	No
Septic Tank	900 gallon
Date Last Pumped	August 1988
Infiltration System Area	210 ft^2
Infiltration System Type	2 foot wide, gravel filled trenches
Effluent Distribution	Gravity flow, 4" perforated pipe

1 Based on information obtained as of 1993.

2.3 Regional Geology and Hydrogeology

St Johns County is underlain by two major geologic units of differing lithologies. The uppermost unit consists of clastic sediments including poorly to moderately consolidated sand, clay, and shell material of Miocene to Holocene age. This overlies a thick sequence of limestone and dolomite, commonly referred to as the Floridan aquifer (Parker et. al, 1955). The top of the limestone of the Floridan aquifer is typically encountered at approximately 400 feet below MSL in this area.



SCALE SCALE: 1"=20'	DRAWN BY: WAF	DATE: 4/93	SITE PLAN	FIGURE: 2.1.2
AYRES ASSOCIATES	CHECKED BY: JMcN	DATE: 4/14/93		
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The Floridan aquifer is the principal source of potable water in the area although potable water is also withdrawn from the surficial and the intermediate aquifers. The homes in the study area utilize private wells which are typically installed in the surficial aquifer at depths of 75 to 100 feet.

2.4 Soils

Soils throughout the subdivision were derived from sandy marine sediments. The morphology of the subdivision soils are, therefore, dominated by sandy profile descriptions.

According to the USDA Soil Conservation Service (SCS) publication "Soil Survey of St. Johns County" the site is located on Adamsville fine sand. The Adamsville series is a somewhat poorly drained soil with a rapid profile permeability. The water table is typically at 20 to 40 inches below grade for approximately 2 to 6 months of the year and below 40 inches for the rest of the year. The typical Adamsville profile has a fine sand texture throughout. Limitations for conventional septic system drainfields are classified as severe with the limitations due to wetness and poor filtration.

III. METHODS OF INVESTIGATION

3.1 Septic Tank Effluent (STE) Characterization

STE Quality: Effluent from the septic tank at the site was collected and analyzed for most typical STE parameters on four to five occasions prior to the initiation of this study as part of the Florida OSDS Research Project (Ayres Associates, 1989). The septic tank effluent was collected and analyzed on three occasions (November 15, 1990, November 5, 1991 and January 7, 1993) as part of the SDA research effort. The samples were obtained from a septic tank effluent basin that was installed between the septic tank and the infiltration system. The more recent wastewater quality data were then compared with prior results and with literature values for STE quality.

A homeowner's survey was also conducted immediately prior to the 1992-1993 sampling to determine types of cleaning products used in the home, thereby determining the types of surfactants that could potentially affect groundwater quality in the area. The homeowner's survey is included in Appendix A.

STE Quantity: The wastewater flow at the home was estimated by reading water meters over several intervals during the study. The water meters were installed at several points on the household water system. A master meter was installed on the main supply line from the household well which monitored total water use. Individual meters were then installed on the exterior hose bibs to monitor outdoor water use. The home did not have an in-ground lawn sprinkler system. The home used a water to air heat pump sytem for household heating so an additional meter was installed on the downstream side of the heat pump to monitor its water use which discharged to the ground outside the house. By subtracting out exterior water use, an estimate of flow was obtained that could be used to estimate wastewater loading to the OSDS. Meter readings were also recorded immediately prior to and after the installation of monitoring wells and groundwater sampling because large amounts of outside water were used during these periods. Water use recorded during these periods was then subtracted from the total water usage.

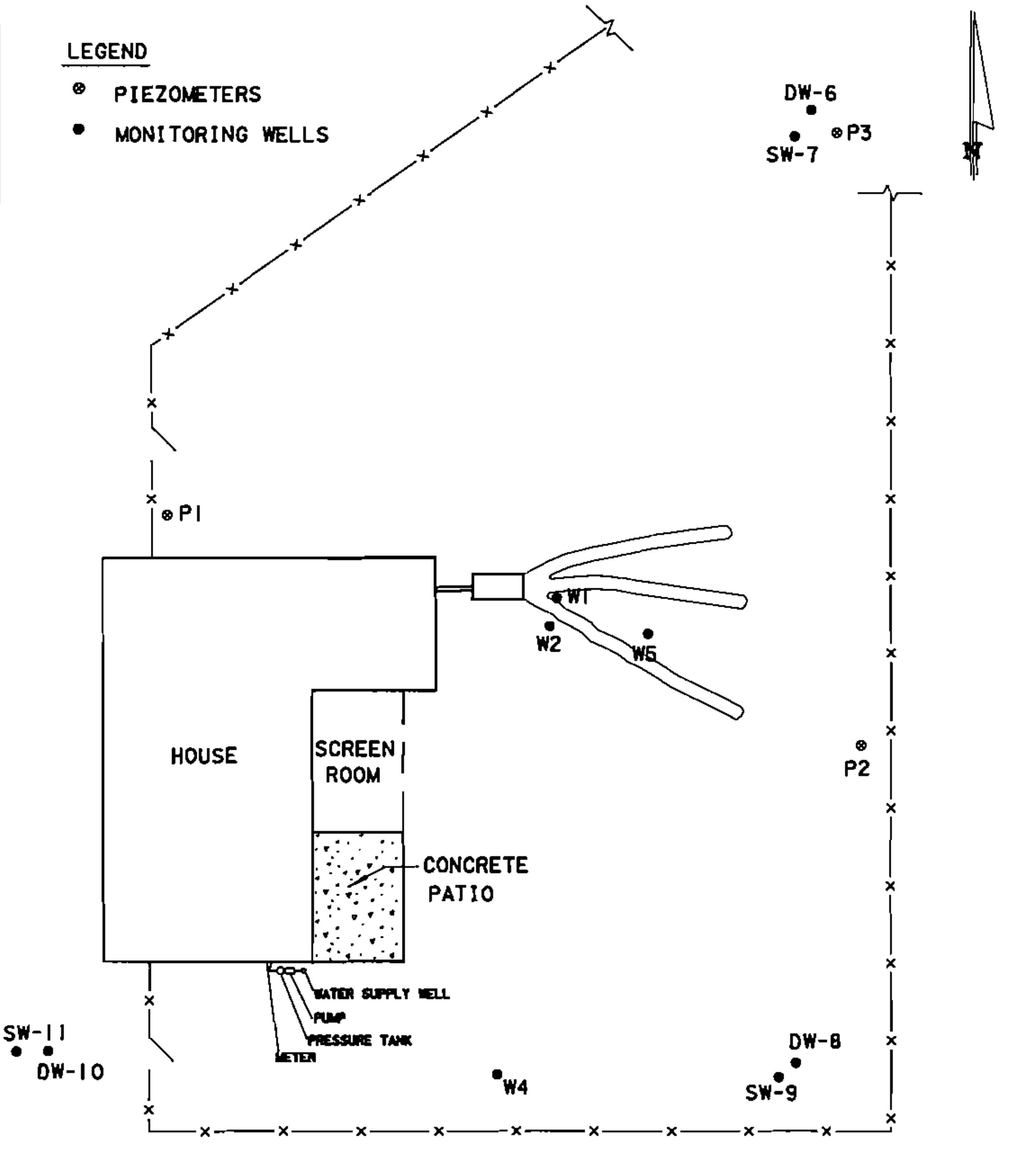
3.2 Groundwater Monitoring Equipment Installation

Three types of groundwater monitoring equipment including piezometers, groundwater monitoring wells, and a modified gas vapor probe were used at the site.

Piezometers: Three groundwater piezometers were installed at locations around the OSDS. These are shown on Figure 3.2.1 as P1, P2 and P3. Piezometers were constructed by coupling a 2-inch diameter, 0.010 inch slotted, 3 foot long Schedule 40 PVC well screen to approximately ten feet of blank 2-inch diameter, Schedule 40 PVC pipe. The piezometers were installed in native soil to a depth of approximatley one to two feet below the water table surface using a stainless steel hand auger. The piezometers were used to determine groundwater elevations and to estimate the direction of groundwater flow.

Monitoring Wells: Four groundwater monitoring wells were installed near the subsurface infiltration system on January 28, 1990. These wells are shown on Figure 3.2.1 as W1, W2, W4 and W5. These monitoring wells were constructed of five feet of 2-inch diameter, 0.010 inch slotted Schedule 40 PVC well screen coupled to approximately seven feet of blank Schedule 40 PVC pipe. Monitoring wells were installed by hand augering with a stainless steel barrel auger to the water table, then augering through 4-inch diameter casing which was advanced with the auger to three to four feet below the water table. The 2-inch diameter PVC monitoring wells were then installed inside the 4-inch diameter casing. A clean, graded sand pack was placed around the monitoring well and the 4-inch casing was removed leaving the sand packed monitoring well in place. The monitoring wells were developed by pumping them at four to five gallons per minute for five minutes after installation.

Additional groundwater monitoring wells were installed on November 23 and 24, 1992. Nested sets, one shallow monitoring well and one deep monitoring well installed adjacent to each other, of monitoring wells were installed at three locations at the site to determine the vertical hydraulic gradient at the site. The monitoring well locations are shown on Figure 3.2.1 and are identified as DW-6, SW-7, DW-8, SW-9, DW-10 and SW-11.



SCALE SCALE: 1"=20'	DRAWN BY: WAF	DATE: 4/93	MONITORING WELL AND PIEZOMETER LOCATION MAP	FIGURE: 3.2.1
AYRES ASSOCIATES	CHECKED BY: JMW	DATE: 4/1/93		
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Groundwater Protection, Inc. installed the monitoring wells using 8.25 inch outside diameter (OD) hollow stem augers. During the installation of monitoring well DW-6, soil samples were collected at two foot intervals using a split spoon sampler. Standard penetration resistence tests, a measure of soil density, were conducted and the blowcounts recorded at each two foot interval. Soil samples were collected at various intervals from the three deeper boreholes for grain size analysis. Lithologic descriptions were also recorded during the installation of the monitoring wells.

The shallow wells were installed to a depth of approximately 8 feet below ground surface (bgs) and were constructed of five feet of 2-inch diameter, 0.010 inch slotted PVC well screen attached to 2.5 feet of 2-inch diameter blank PVC pipe. The deeper wells installed to a depth of approximately 50 feet bgs and were constructed of 2.5 feet of 2-inch diameter, 0.010 inch slotted well screen coupled to approximately 48 feet of 2-inch diameter solid PVC pipe. The annular space between the well was filled with clean 20/30 silica sand to the top of the well screen. A one foot thick bentonite seal was placed immediately above the sand pack during the construction of the shallow monitoring wells. A one foot thick layer of fine sand was used as a seal above the sand pack in the deeper wells. The remaining annulus was filled with Portland Type I cement to land surface. A protective flush-mounted manhole cover and pad was constructed around the top of the well. The monitoring wells were developed by pumping with a centrifugal pump to remove fine sediment from the sand pack. These wells were not sampled but were used for additional groundwater measurements to determine the direction of groundwater flow and to determine if vertical flow of groundwater was significant at the site. Vertical groundwater flow would influence contaminant transport at the site, causing a downward movement of contaminants as they move away from the site. Well completion diagrams for the monitoring wells installed in November, 1992 and well construction specifications for all monitoring wells and piezometers installed at the site are included in Appendix B.

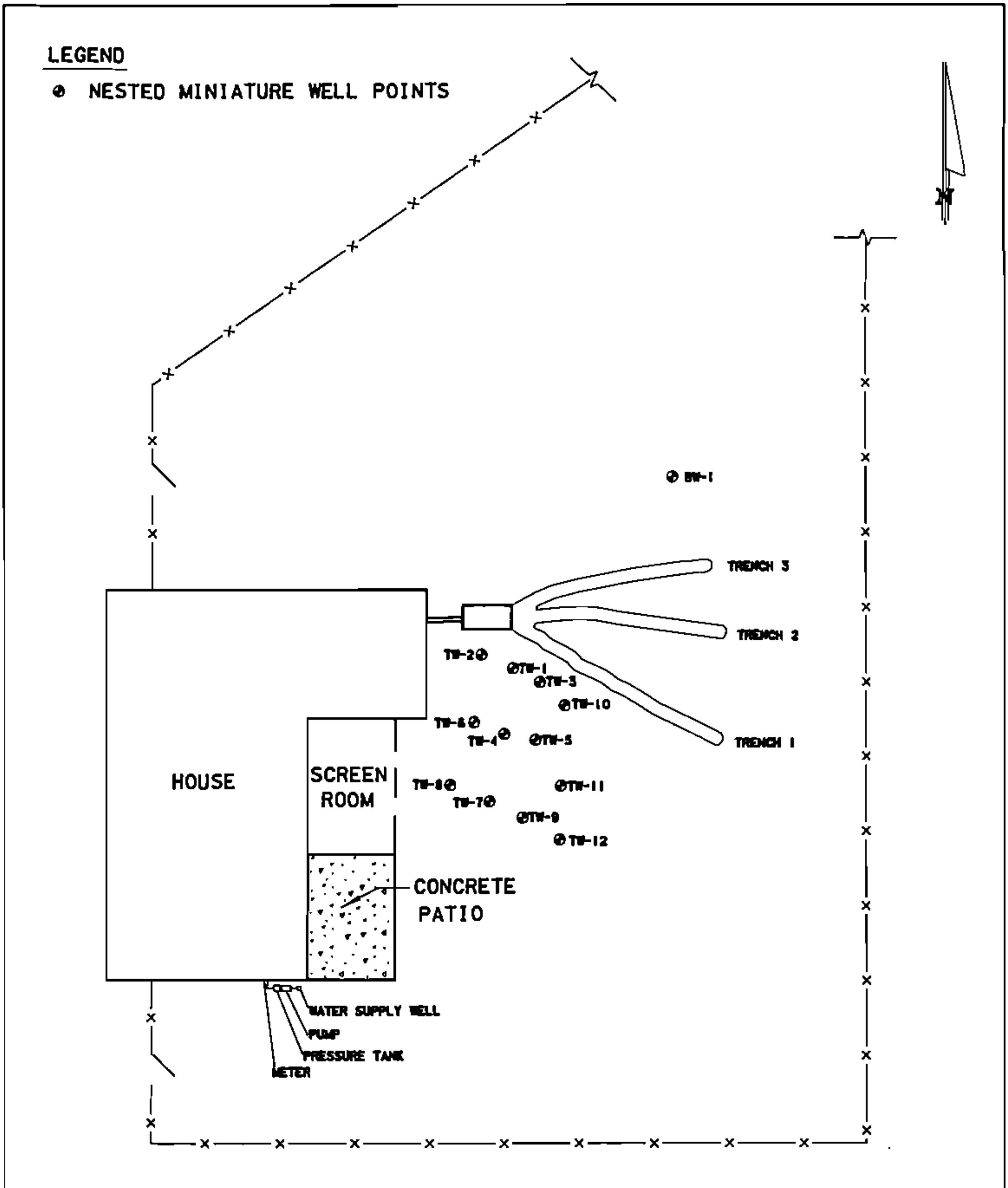
Stainless Steel Probe: A stainless steel probe system originally designed for soil gas vapor monitoring in the unsaturated zone was used to obtain groundwater samples around the site. The probe unit utilized a "push-pull" wellpoint attached to 1/2 inch stainless steel tubing which was driven into the unsaturated zone. Groundwater samples were then obtained through a teflon sampling tube inside the stainless tube by applying suction with a peristaltic pump on the teflon tubing. The entire probe system could then be pulled up and driven in at a new sample location. This system allowed collection of groundwater samples from ten to fifteen different locations per day at the project site, and was especially useful for identifying the location of the contaminant plume.

During the Phase II study a more permanent monitoring network was established. First, the area of impacted groundwater downgradient of the drainfield was further defined using the "push-pull" methodology. A row of eight sample locations were installed along the edge of the southernmost trench (Trench 1) and groundwater samples were obtained from the "push-pull" probe for field screening. Based on these results, thirty miniature stainless wellpoints with teflon tubing were permanently installed within the impacted area downgradient of the infiltration system using the modified gas vapor probe system. Three rows of wellpoints were established. The first row of wellpoints was placed 5 feet downgradient of Trench 1. Each additional row was placed approximately 5 feet farther downgradient. Each row contained four sample points. See Figure 3.2.2 for the locations of the sample points. At sample points T-1 through T-6, wellpoints were installed at three depths: approximately 6 feet below ground surface (bgs), 12 feet bgs, and 20 feet bgs. Wellpoints were installed at two depths, approximately 6 feet bgs and 20 feet bgs, at sample locations T-7 through T-9. Sample points T-10 through T-13 only contained one wellpoint that was installed at approximately 6 feet bgs. A background sample point was also installed upgradient of the drainfield with separate wellpoints at approximately 5 feet, 10 feet and 15 feet below ground surface. Groundwater samples were obtained from these well points for laboratory analysis of the same water quality parameters as the monitoring wells.

3.3 Groundwater Elevations and Flow Direction

Groundwater Flow Direction: Groundwater movement in shallow aquifers is generally governed by forces of gravity and, therefore, moves from areas of higher water table elevations to areas of lower water table elevations. Water table elevations can be contoured to distinguish areas of higher or lower water table elevation. The groundwater flow direction is perpendicular, or normal to these water table elevation contour lines. Water table elevation contour lines are determined by obtaining the depth to groundwater at various locations and referencing that depth to a known elevation at the site.

An initial direction of groundwater flow was determined by the installation of three piezometers, P-1 through P-3, at the site. The elevations of the tops of the piezometer casings were initially surveyed by Ayres Associates on November 27,1993 and referenced



SCALE: 1"=20'	DRAWN BY: WAF	DATE: 4/93	MINIATURE WELL SAMPLE POINT LOCATION MAP	FIGURE: 3.2.2
AYRES ASSOCIATES	CHECKED BY: JMS	DATE: 4/16/93		
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granular soils. Color was described using Munsell Soil Color Charts. Soil descriptions were in accordance with the Unified Soils Classification System.

Particle Size Analysis: Soil samples obtained during well installation were sent to Driggers Engineering Services of Clearwater, Florida, for particle size analysis. Particle size analysis was conducted in accordance with ASTM D 422-72 "Standard Method for Particle-Size Analysis of Soils".

3.5 Groundwater Sampling

Preliminary field screening of groundwater for chloride and conductivity was conducted on December 14-15, 1992 using the "push-pull" temporary stainless steel probe. Results of the preliminary field screening indicated that impacted groundwater extended beyond the initial plume outlined in November, 1990. Based on these data, a network of 12 sample points were installed in the area on December 15-17, 1992 and January 5-6, 1993. The chloride and conductivity values obtained during the preliminary screening also varied with depth. Background wellpoints were then installed approximately 15 feet upgradient of the infiltration system to determine if the values observed were due to the vertical movement of the contaminant plume or could be attributed to natural variations of chlorides in the native soil.

Groundwater samples from thirty wellpoints and 2 monitoring wells, SW-7 and W5, were obtained on January 7, 1993. Groundwater from these wellpoints and monitoring wells were subsequently sampled for the following water quality parameters:

- Chloride
- Foaming Agents (MBAS)
- Total Dissolved Solids
- Ammonia Nitrogen
- Nitrate-Nitrite Nitrogen
- Total Phosphorous
- Total Organic Carbon
- Fecal Coliforms

Results of the monitoring efforts are presented in the next section.

IV. RESULTS

4.1 Septic Tank Effluent (STE) Characterization

STE Quality: The septic tank effluent was sampled at the site to assess the quality of wastewater discharged to the OSDS drainfield. Table 4.1.1 is a summary of septic tank effluent (STE) quality. Appendix E includes the STE laboratory results. The table lists the three (3) sampling results conducted for this study and the average values for the prior results at the site for the Florida OSDS Research project. The average STE values of the 1990 through 1993 sampling events generally exceed the prior average for typical STE parameters sampled at the site. The average concentration of MBAS obtained during the current study was six times the prior average. The average chloride and TKN values were approximately twice the prior average. Average values for BOD, specific conductance, total organic carbon, oil and grease were also increased over their prior averages. Average 1990-1993 STE values for TSS and TDS decreased when compared to the prior results. Samples were not obtained for sulfate and fecal streptococcus analysis during the Florida OSDS Research project.

The results indicated that concentrations of several STE parameters were increased over the concentrations found in the prior study and also appear to have increased over time, particularly during 1992-1993. Imminent system failure was noted during the site visit in November, 1992 as the STE basin was regularly overflowing. Tree roots were found growing in one of the three drainage pipes. The tree roots were removed from the pipe thus correcting the problem immediately prior to the January sampling. The removal of the tree roots did not appear to effect the levels of STE pollutants during the January sampling.

Normally a septic tank provides a relatively composite sample due to the 2 to 3 day retention time of the wastewater in the tank. However, if the baffles of the septic tank were submerged during this period, short-circuiting through the septic tank may have occurred, thus destroying the composite nature of the sample. Partial failure of the system could result in a decrease in removal of STE pollutants and subsequent increase in concentrations of these pollutants. However, an increase in suspended solids would also be expected if the septic tank baffles were submerged. An increase in input of these parameters by growing children may be another explanation for the noted increase in STE concentrations.

Table 4.1.1. Summary of Septic Tank Effluent Quality (mg/L unless otherwise noted)

Parameter	Average from Previous Sampling Events *	11/15/90	11/5/92	1/7/93	Average STE for 90-93
BOD	139	124	204	208	179
Foaming Agents (MBAS)	5	20	48	24	31
Total Suspended Solids (TSS)	93	66	74	38	59
Total Dissolved Solids (TDS)	415	264	424	472	387
Specific Conductance +	712	800	1,100	1,200	1033
Chloride	24	40	58	61	53
Sulfate	--	--	6	3	5
Total Phosphorus	15	17	17	16	17
Total Nitrogen	--	--	73	78	76
Total Kjeldahl Nitrogen	36	48	73	78	66
Ammonia Nitrogen	--	--	--	75	75
Nitrate Nitrogen	0.06	0.03	0.01	0.01	.02
Total Organic Carbon	56	55	76	89	73
Oil and Grease	25	38	40	34	37
Fecal Coliforms **	5.45×10^6	--	16×10^6	6.6×10^6	1.02×10^7
Fecal Streptococci**	--	--	230	470	350

* Results shown are the mean values for five sampling events conducted during the Florida OSDS research study.
\+ Units are µhos/cm
** Units are colonies/100 ml; averages are based on a geometric mean
-- Not sampled

With the exception of total nitrogen , average STE concentrations encountered in this study are comparable to the range of concentrations for STE parameters found in the literature (Stolt and Reneau, 1991). Total nitrogen values from eight studies summarized by Stolt and Reneau range from 29.8 mg/L to 60.8 mg/L. Ayres Associates (1989) reported total nitrogen values from 33 to 54 mg N /L in a study of eight septic systems in Florida. The total nitrogen average for this study from 1990-1993 was 76 mg/L indicating a somewhat higher output of nitrogen from the septic tank.

STE Quantity: Water meter readings were collected at the site at eleven different dates from November, 1990 to January, 1993. These data were used to estimate the average wastewater flow to the OSDS infiltration area at the home. Water used by Ayres Associates during the installation of monitoring wells and groundwater sampling was recorded and subtracted from the normal total water usage at the site. Table 4.1.2 is a summary of water use data collected at the study residence and presents estimates of wastewater loading to the OSDS infiltration area.

Total water use averaged 1170 gpd at the site. The water usage attributed to the heat pump averaged 979 gpd. The outside water use attributed to one of the faucets averaged 5 gpd. Another meter was installed on the other outside faucet but was non-operational

Table 4.1.2. Average Daily Water Use Summary

Total Water Use (gpd)	Heat Pump (gpd)	Exterior Use (gpd)	Estimated Wastewater Flow (gpd)	Estimated Wastewater Loading (gpd/ft^2)*
1170	979	5	186	0.89

* Based on an infiltration system area of 210 ft^2

throughout most of the study and water use data for this faucet is not included. After subtracting the exterior water use from the total water use, the estimated wastewater flow was 186 gpd and the estimated wastewater loading to the infiltration area was calculated to be 0.89 gpd/ft^2.

4.2 Groundwater Elevations and Flow Direction

Groundwater Flow Direction: Initial piezometer readings indicated the general direction of groundwater flow at the site was south-southwest, toward the St. Johns River. Subsequent depth to groundwater measurements confirmed the groundwater flow direction. The groundwater gradient was relatively constant across the site and was calculated to be approximately 0.0027 feet/foot using the groundwater elevation data from January 12, 1993.

In November, 1990 the depths to groundwater at the site ranged from 5 to 6 feet bgs. Depth to groundwater at the site, during the 1992-1993 study, ranged from approximately 1.5 feet to 4 feet bgs. The lowest relative groundwater elevations were recorded at monitoring well SW-11 located in the southwest portion of the site. The highest relative groundwater elevations were calculated to be at the piezometer P-3 which is located in the northeastern corner of the site. Table 4.2.1 lists the relative groundwater elevations calculated for depth to water measurements obtained from November, 1992 through January, 1993. Figure 4.2.1 shows the groundwater elevations and contours calculated from data collected on January 12, 1993.

One of the tasks of the study was to determine if a vertical component of flow was present at the site and, if so, whether that vertical component was great enough to cause the contaminant plume to "dip" into a deeper zone. Groundwater elevation data (Table 4.2.1) indicates that with the possible exception of the nested monitoring well set in the southeast corner of the site, DW-8 and SW-9, no measurable vertical component of flow was present at the site. The groundwater elevation difference between SW-9 and DW-8 ranges from 0.08 to 0.10 feet measured over the distance between the top of the water table at the shallow well to the top of the screened interval at the deep well. This distance was approximately 46 feet for a vertical gradient of .002 feet/foot which was slightly less than the horizontal gradient. The vertical gradient of .002 feet/foot in this area was consistent throughout the study. Thus, it appeared that some potential for downward groundwater flow existed at the site.

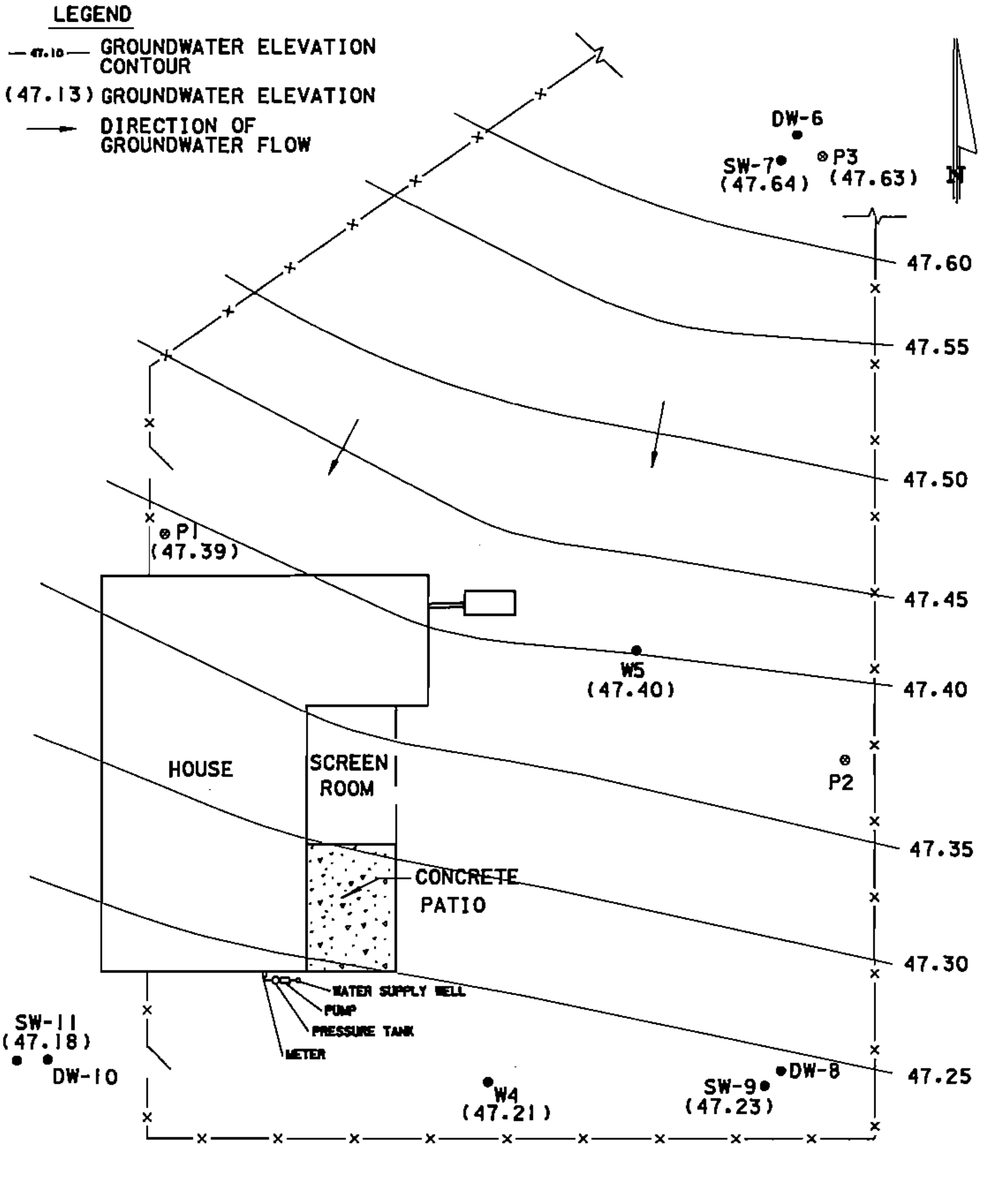
Unsaturated Zone Thickness: The average water table elevation and the ranges of water table elevations are presented in Table 4.2.2. Table 4.2.2 also shows the range of unsaturated soil thickness between the infiltrative surface and the water table for wells near the infiltration area.

At the time of the highest measured groundwater levels (January 12, 1993), the depth to groundwater at the site for the monitoring well closest to the infiltration area (W5) was 2.18 feet bgs. At that time the thickness of unsaturated soil beneath the infiltration system at the site was 0.34 feet. Monitoring wells, W1 and W2, the closest wells to the infiltration area, were abandoned on January 6, 1992. The unsaturated soil thickness at the site ranged from 1.44 to 0.34 feet during the Phase II study period and the water table was commonly within 1 foot of the infiltrative surface indicating that treatment efficiency may be reduced.

Table 4.2.1 Relative Groundwater Elevation Data for Individual Home in St. Johns County

Well ID. #	Top of Casing Elevation (ft.)	NOVEMBER 24, 1992 Depth to Water (ft.)	NOVEMBER 24, 1992 Relative W.T.E. (ft.)	DECEMBER 14, 1992 Depth to Water (ft.)	DECEMBER 14, 1992 Relative W.T.E. (ft.)	JANUARY 5, 1993 Depth to Water (ft.)	JANUARY 5, 1993 Relative W.T.E. (ft.)	JANUARY 12, 1993 Depth to Water (ft.)	JANUARY 12, 1993 Relative W.T.E. (ft.)	Average W.T.E.
W1	49.64	2.67	46.97	2.99	46.65	3.24	46.40	*	- -	46.67
W2	49.66	2.73	46.93	3.04	46.62	3.33	46.33	*	- -	46.63
W4	49.28	2.53	46.75	2.83	46.45	3.12	46.16	2.07	47.21	46.64
W5	49.58	2.66	46.92	2.98	46.60	3.28	46.30	2.18	47.40	46.81
P1	49.87	- -	- -	3.28	46.59	- -	- -	2.48	47.39	46.99
P3	52.76	5.63	47.13	5.97	46.79	6.29	46.47	5.13	47.63	47.01
DW-6	53.62	6.45	47.17	6.82	46.80	7.16	46.46	5.93	47.69	47.03
SW-7	52.46	5.31	47.15	5.65	46.81	6.00	46.46	4.82	47.64	47.02
DW-8	48.94	2.26	46.68	2.56	46.39	2.81	46.13	1.81	47.13	46.58
SW-9	48.88	2.11	46.77	2.41	46.47	2.65	46.23	1.65	47.23	46.68
DW-10	49.71	3.02	46.69	3.30	46.41	3.63	46.08	2.54	47.17	46.59
SW-11	49.58	2.86	46.72	3.17	46.41	3.41	46.17	2.40	47.18	46.62

W.T.E. Water Table Elevation-Elevations are relative to an arbitrary benchmark datum set up on the site.
* Monitoring Wells W1 and W2 were abandoned on January 6, 1993.
-- No W.T.E. measurement obtained



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RELATIVE GROUNDWATER ELEVATION CONTOUR MAP
JANUARY 12, 1993

FIGURE: 4.2.1

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Table 4.2.2. Average Water Table Elevation and Unsaturated Soil Thickness

WELL ID #	AVERAGE WATER TABLE ELEVATION (ft.)	WATER TABLE ELEVATION RANGE (ft.)	UNSATURATION ZONE RANGE* (ft. below infiltrative surface)
W1	46.67	46.40 - 46.97	1.34 - 0.77 +
W2	46.63	46.33 - 46.93	1.41 - 0.81 +
W4	46.64	46.16 - 47.21	N/A
W5	46.81	46.30 - 47.40	1.44 - 0.34
P1	46.99	46.59 - 47.39	N/A
P3	47.01	46.47 - 47.63	N/A
DW-6	47.03	46.46 - 47.69	N/A
SW-7	47.02	46.46 - 47.64	N/A
DW-8	46.58	46.13 - 47.13	N/A
SW-9	46.68	46.23 - 47.23	N/A
DW-10	46.59	46.08 - 47.17	N/A
SW-11	46.62	46.17 - 47.18	N/A

* Based on elevation of 47.74 ft. for infiltrative surface of drainfield at observation port T-1.
N/A Wells not in area of drainfield.
\+ Data was not available on 1/12/93, the day of highest water table elevation, as monitoring wells W1 and W2 had been abandoned.

4.3 Subsurface Characterization

Subsurface Lithology: The subsurface lithology is described from split spoon samples and auger cuttings obtained during the installation of the deep monitoring wells. Soil boring logs are included in Appendix C. The subsurface lithology at the site consisted of approximately four units with observed differences in lithology based primarily on changes in color as the texture remained fine-grained throughout. The units and the depths they were encountered are as follows: 1) very dark to dark gray fine-grained quartz sand with roots typical of topsoil-0 to 4 feet below ground surface (bgs); 2) a light gray to white fine grained quartz sand with some gray streaks of clay-4 to 20 feet bgs 3) light gray to light brownish gray fine-grained quartz sand-20 to 30 feet bgs; and 4) dark gray to gray fine-grained quartz sand-30 to 50 feet bgs.

Particle Size Analysis: A grainsize data summary and grainsize distribution curves are presented in Appendix D. These data indicate that approximately 85% to 97% by weight of the soil samples obtained were composed of fine sand. The percentage of fines (silts and clays) in the samples ranged from 0.9% in a soil sample obtained from DW-10 at 10 to 12 feet bgs to 6.0% in a soil sample obtained from DW-8 at 3 to 4 feet bgs. The samples obtained from the top few feet of sediment contained more fines than samples obtained at deeper intervals. Percentages of medium sand were generally less than 5% with the exception of soil samples obtained at approximately 27 to 32 feet from borings DW-6 and DW-10 which contained approximately 10% medium sand.

4.4 Water Quality Results

Thirty groundwater samples were obtained from the wellpoints installed at the site and taken to Southern Analytical Laboratory for analysis. In addition, groundwater was also obtained for analysis from one well located near the infiltration area and one well located upgradient of the infiltration area. The laboratory results indicated that the plume of groundwater containing constituents characteristic of STE had extended further downgradient than previous results had shown. The laboratory results are summarized in Table 4.4.1. Final laboratory results are included in Appendix E. Figures 4.4.1 through 4.4.4 show concentrations of various parameters in groundwater obtained six feet below ground surface.

Chloride concentrations six feet bgs are shown on Figure 4.4.1. Chloride concentrations were above background (BW-1-5) levels in groundwater obtained from all sample locations with the exception of TW-11. These results indicate dthat groundwater in the area was impacted by septic tank effluent.

Chloride concentrations did appear to increase with depth, however, background chloride concentrations also increased with depth. Upgradient sample results at depths of 10 and 15 feet bgs were 31 mg/L and 27 mg/L chloride, respectively. Groundwater from only one downgradient wellpoint installed at the 12 foot depth, TW-3-12', had a concentration above those levels. Although the chloride concentrations obtained from groundwater at the twenty foot depths were elevated above the background level of 27 mg/L the concentrations were consistently in the range from 40 mg/L to 44 mg/L. Although a background wellpoint was not installed at a 20 foot depth, it was observed during field screening that chloride and conductivity values generally increased with depth and concentrations were similar to those obtained at 20 feet from the permanent wellpoints. It was therefore assumed that the increased chloride concentrations with depth were not related to the OSDS. A background wellpoint should be installed at the 20 foot depth to confirm this assumption.

Table 4.4.1 Summary of Water Quality Results (mg/L unless otherwise noted) January 7, 1993

Sample Point	Sample Depth (ft. bgs)	Cl^-	MBAS	TDS	NH_3-N	NO_3-N	TP	TOC	Fecal Coliforms (cols/100mL)
STE	N/A	61	24.00	472	75.00	0.01	16	89.0	6.6×10^6
TW-1	6	61	5.70	380	48.00	<0.01	14.00	26.0	200
	12	13	<0.05	118	0.14	<0.01	0.02	4.5	<10
	20	44	<0.05	322	0.01	2.10	0.05	1.5	<2
TW-2	6	51	0.40	330	19.00	<0.01	13.00	17.0	<1
	12	14	<0.05	124	0.08	<0.01	0.02	3.5	<1
	20	40	<0.05	320	<0.01	2.90	0.15	1.9	<1
TW-3	6	59	0.37	440	14.00	23.00	5.60	5.6	<2
	12	41	0.06	126	0.04	<0.01	0.26	4.0	<1
	20	41	0.07	304	0.02	2.40	0.02	1.7	<1
TW-4	6	65	5.50	420	26.00	<0.01	5.20	17.0	<1
	12	13	<0.05	124	0.03	<0.01	0.10	2.8	<1
	20	43	<0.05	316	0.01	2.60	0.02	1.5	<1
TW-5	6	55	4.70	354	4.50	<0.01	12.00	15.0	<1
	12	16	<0.05	136	0.01	<0.01	0.10	3.5	<1
	20	35	<0.05	264	0.08	<0.01	0.02	3.2	<1
TW-6	6	88	0.83	324	37.00	<0.01	8.40	13.0	<1
	12	13	<0.05	134	0.04	<0.01	0.08	3.6	<1
	20	43	<0.05	332	<0.01	2.70	0.03	1.7	<2
TW-7	6	83	0.72	360	29.00	<0.01	5.20	22.0	<2
	20	43	<0.05	336	0.02	2.90	0.02	1.7	<1
TW-8	6	24	0.14	158	19.00	<0.01	3.50	19.0	<10
	20	42	<0.05	316	0.03	2.30	0.02	1.5	<1

Table 4.4.1. Continued

Sample Point	Sample Depth (ft. bgs)	Cl^-	MBAS	TDS	NH_3-N	NO_3-N	TP	TOC	Fecal Coliforms (cols/100mL)
TW-9	6	76	0.96	378	22.0	0.08	12.00	7.4	<1
	20	43	<0.05	320	0.03	2.80	0.06	1.9	<1
TW-10	6	53	3.30	374	8.30	<0.01	9.60	14.0	<1
TW-11	6	13	<0.05	138	0.64	<0.01	0.82	2.5	<1
TW-12	6	69	0.12	338	12.00	<0.01	0.33	4.3	<1
BW-1	5	13	<0.05	56	0.15	<0.01	0.02	4.3	<1
	10	31	<0.05	66	0.10	<0.01	0.02	3.8	<1
	15	27	<0.05	190	0.10	<0.01	0.01	1.3	<1
SW-7	10	15	0.05	248	0.79	<0.01	0.04	32.0	<10
W5	10	49	0.31	362	3.00	19.00	5.20	7.7	6

N/A- Not applicable

Cl^-- Chloride

MBAS- Methylene Blue Active Substance

TDS- Total Dissolved Solids

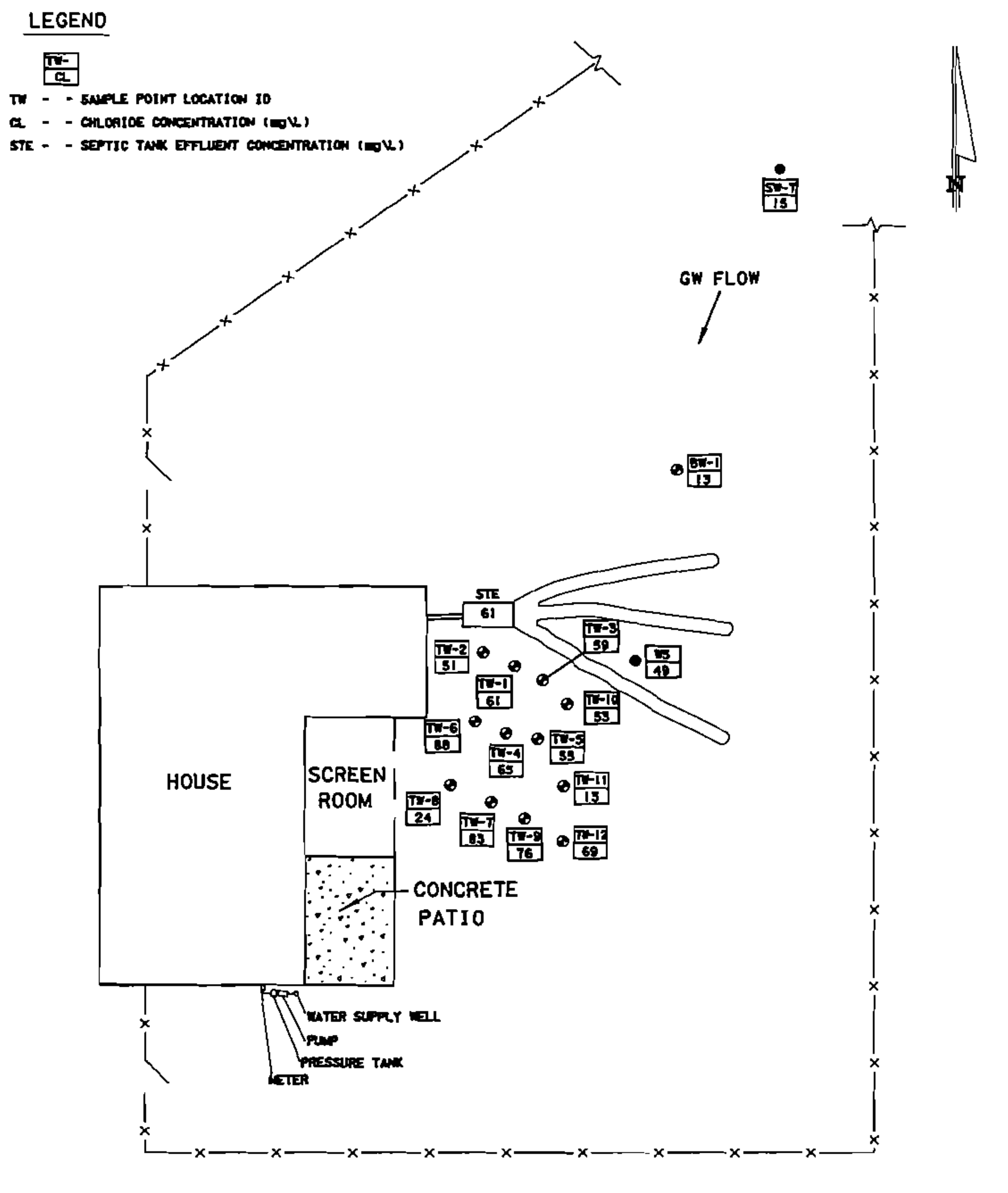
NH_3-N- Ammonia Nitrogen

NO_3-Nitrogen-Nitrate-Nitrogen

TP-Total Phosphorus

TOC-Total Organic Carbon

Total phosphorus concentrations six feet bgs are shown in Figure 4.4.2. All groundwater obtained from the sample points located six feet bgs had concentrations of total phosphorus higher than background concentrations. Groundwater obtained from the sample points closest to the septic tank and Trench 1, TW-1 and TW-2, had total phosphorus concentrations similar to the STE sample obtained during the same sampling event indicating limited treatment or adsorption of phosphorus was occurring at the time of sampling. Previous studies (Stolt and Reneau, 1991; Cogger, et al. 1988) have shown that elevated water tables reduce phosphorus attenuation, especially in sandier soils that have less adsorptive capacity, initially. Total phosphorus concentrations in groundwater obtained from the 12 and 20 foot depths were less than 0.20 mg/L which is similar to the background concentrations at 10 feet (0.02 mg/L) and 15 feet (0.01 mg/L).



SCALE				FIGURE:
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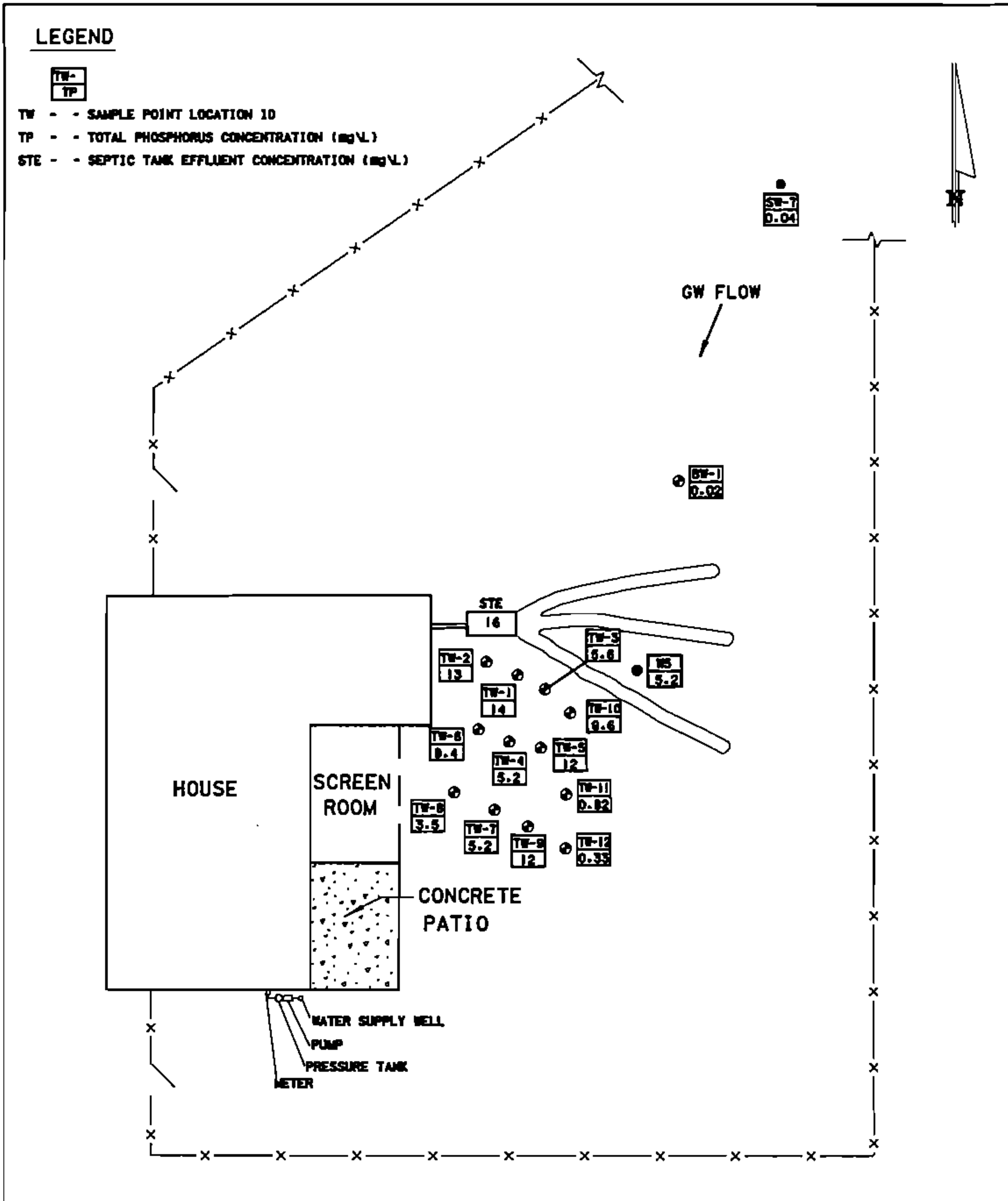

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TOTAL PHOSPHORUS CONCENTRATIONS 6' BGS, 3' TO 4' INTO THE WATER TABLE

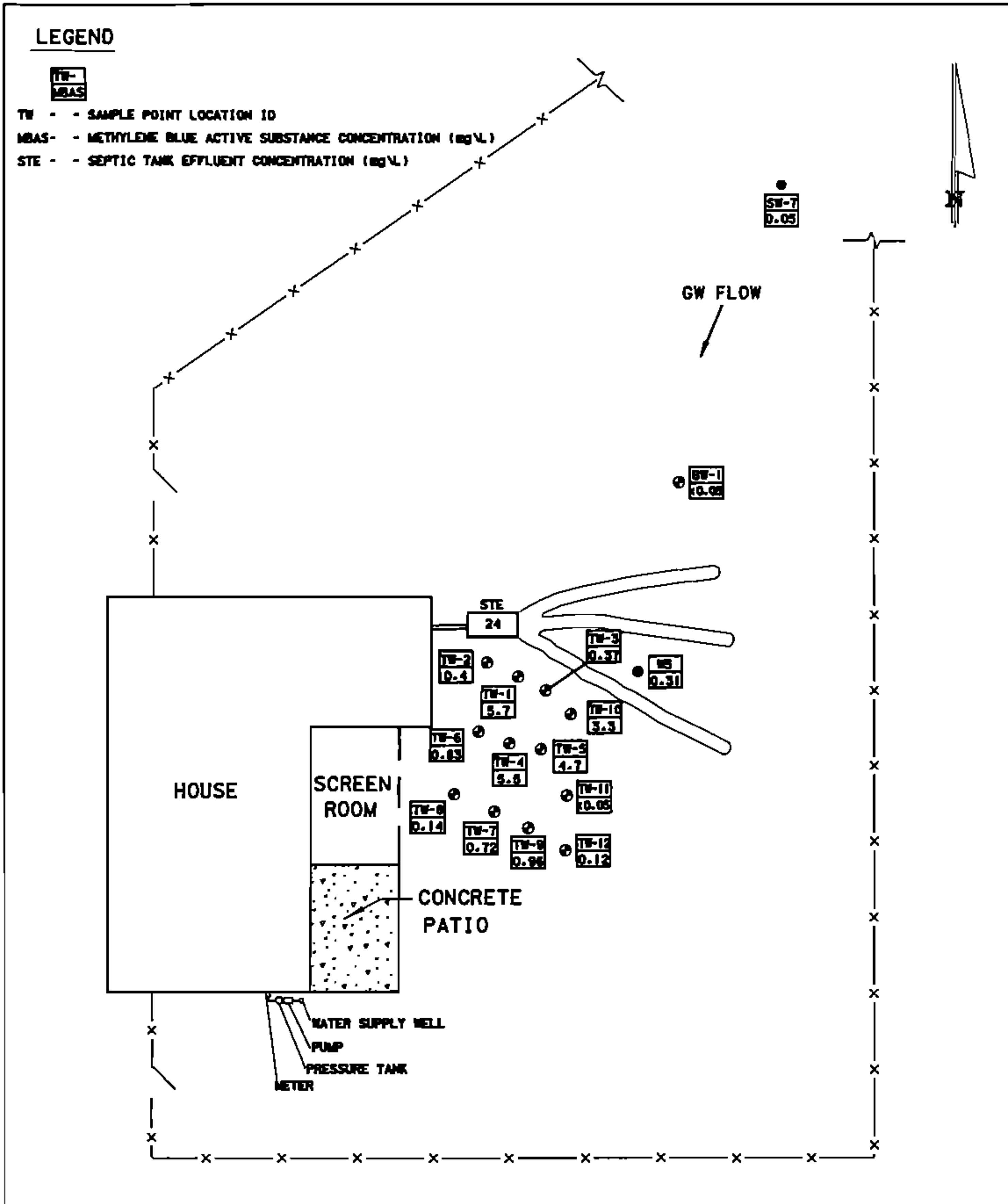
FIGURE: 4.4.2

MBAS concentrations at six feet bgs are shown in Figure 4.4.3. With the exception of TW-11, groundwater obtained from the six foot depth contained concentrations of MBAS above detection limits. Groundwater obtained from four of the sample points, TW-1, TW-4, TW-5, and TW-10 had MBAS concentrations of 5.7 mg/L, 5.5 mg/L, 4.7 mg/L and 3.3 mg/L, respectively. Groundwater obtained from the remaining sample points contained less than 1 mg/L MBAS. MBAS concentrations in groundwater obtained from the 12 and 20 foot depths were generally not detectable (<0.05 mg/L). MBAS was detected in groundwater collected from TW-3-12' , TW-3-20', and the monitoring well SW-7 but the concentrations were less than 0.07 mg/L.

Figure 4.4.4 shows the ammonia nitrogen and nitrate-nitrite-nitrogen concentrations at six feet below ground surface. Concentrations of ammonia nitrogen in groundwater samples obtained from the wellpoints at 6 feet bgs were consistently elevated. Groundwater obtained at the sample points TW-1, TW-4, TW-6, TW-7, TW-8, and TW-9 at 6 feet bgs contained NH_3-N concentrations greater than 20 mg/L. Nitrate-nitrite-nitrogen concentrations in the groundwater obtained were below detection limits at most sample points. These results indicate that anoxic conditions may be present near the infiltration area and nitrification is being inhibited. Ammonia nitrogen and NO_3-N concentrations were either at or below background (0.10 mg/L and <0.01 mg/L, respectively) at the 12 foot depth. However, at the 20 foot depth NO_3-N concentrations in groundwater ranged from 2.1 mg/L to 2.9 mg/L indicating either an unidentified source of nitrate at that depth or a "pulse" of nitrate from a time when anoxic conditions were not present. Groundwater obtained from 15 feet in an area upgradient of the infiltration area did not have elevated background concentrations making the argument for an unidentified source less likely. However, groundwater was not obtained from a 20 foot depth upgradient of the system.

With the exception of TW-11-6' and TW-12-6', total organic carbon (TOC) concentrations were above background (4.3 mg/L) concentrations in groundwater obtained from all wellpoints installed at the six foot depth. Concentrations ranged from 7.4 mg/L in groundwater obtained from TW-9-6' to 26 mg/L in groundwater obtained from TW-1-6'. TOC concentrations were generally at or below background levels (3.8 mg/L @ 10 ft, 1.3 mg/L @ 15 ft) at the 12 foot and 20 foot depths.

Results from the total dissolved solids (TDS) analyses were more difficult to interpret. TDS concentrations in all groundwater obtained from the wellpoints installed at the six foot depth were elevated above background (56 mg/L). TDS concentrations in the groundwater



SCALE: 1"=20'	DRAWN BY: WAF — DATE: 4/93 CHECKED BY: — DATE: 4/20/93 APPROVED BY: — DATE:	MBAS CONCENTRATIONS 6' BGS, 3' TO 4' INTO THE WATER TABLE	FIGURE: 4.4.3
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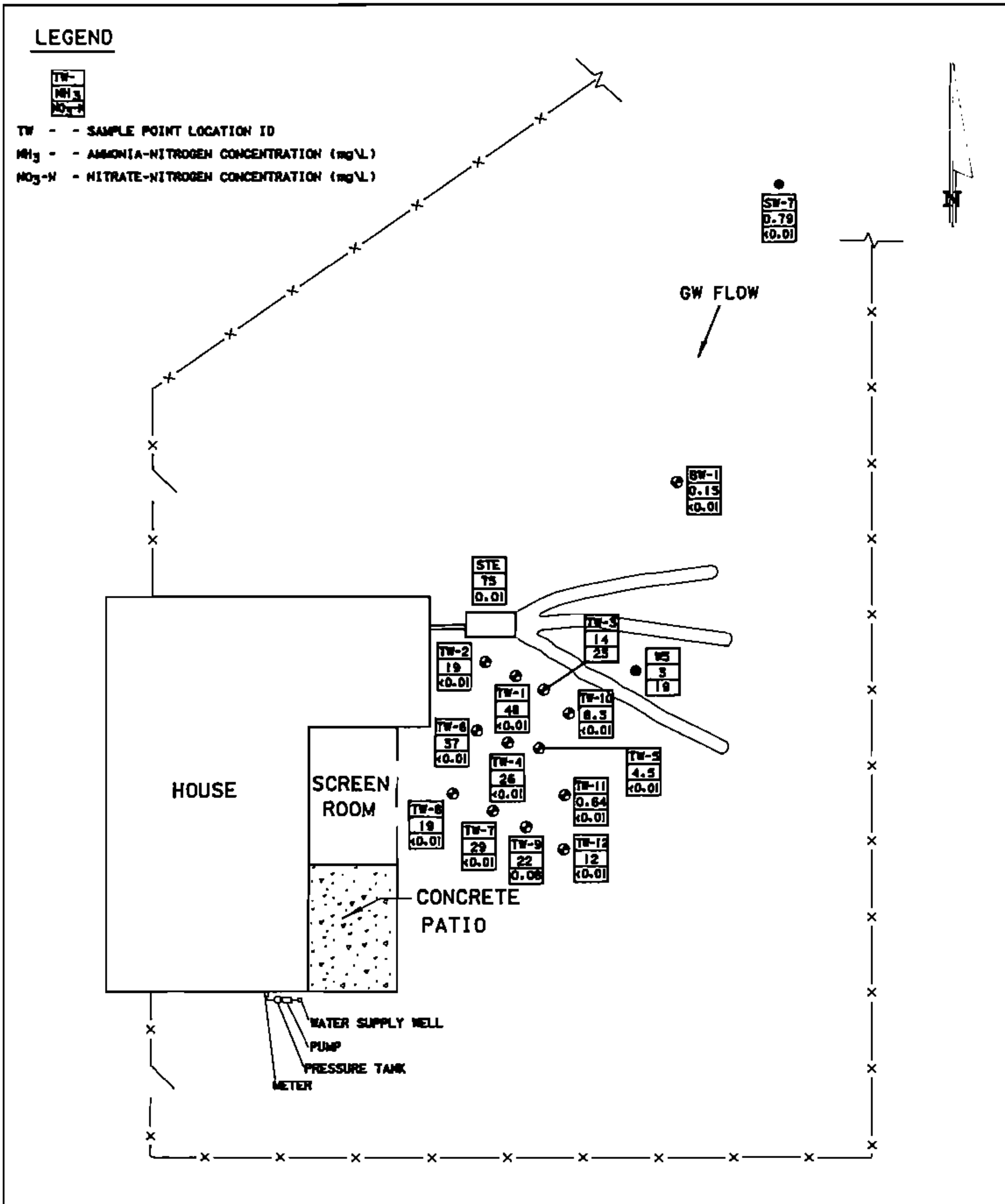

SCALE			AMMONIA-NITROGEN AND NITRATE-NITRITE-NITROGEN CONCENTRATIONS 6' BGS, 3' TO 4' INTO THE WATER TABLE	FIGURE:
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obtained ranged from 138 mg/L to 440 mg/L. Groundwater obtained from the 12 foot and 20 foot depths also contained TDS above background levels.

Fecal coliform bacteria, an indicator of human waste, were noted in groundwater obtained from one of the wellpoints and one of the monitoring wells. TW-1-6' and W5 contained 200 colonies/100 mL and 6 colonies/100 mL, respectively. Fecal coliforms were not detected in groundwater obtained from the 12 or 20 foot depths.

In summary, groundwater analytical results indicated that the extent of impacted groundwater extends beyond the plume that was initially defined using the "push-pull" methodology. According to the most recent laboratory results, the downgradient extent of the plume has not been defined. The expansion of the plume may be attributed to the higher water tables and the partial failure of the OSDS. Several indicator substances, including MBAS, were found in detectable quantities in groundwater located 20 to 25 feet from the infiltration area.

V. SUMMARY AND CONCLUSIONS

Ayres Associates was contracted by the SDA in May, 1992 to conduct the Phase II portion of a study initiated in November, 1990. The objectives of the second phase of the project was to delineate the contaminate plume at the OSDS of a single family home in St. Johns County, Florida and evaluate the fate and transport of key water quality parameters of interest to the SDA.

To accomplish these objectives, Ayres Associates obtained samples of the STE to determine household wastewater quality; metered various water use functions to determine wastewater loading to the infiltration area; installed three nested sets of monitoring wells to determine if a vertical groundwater gradient was present at the site; outlined the location of groundwater impacted by the OSDS ; installed thirty miniature wellpoints and collected groundwater samples from these wellpoints and two permanent onsite monitoring wells; and analyzed the groundwater samples for parameters characteristic of STE.

A summary of the results and the conclusions obtained from this study are as follows:

- Average concentrations of several STE parameters were increased over the concentrations found in the prior Florida OSDS Research study and also appear to have increased over time, particularly during 1992-1993. The average concentration of MBAS was 6 times the average of the previous study and average values for TKN and chloride were approximately twice those of the previous study.

- The total nitrogen average in STE for this study (75.5 mg/L) was higher than the normal range of values for total nitrogen in STE found in the literature. Stolt and Reneau (1991) summarized eight studies of septic tank effluent. Literature values for total nitrogen in these studies ranged from 29.8 to 60.8 mg/L. Ayres Associates (1989) reported total nitrogen values from 33 to 54 mg N /L in a study of eight septic systems in Florida.

- The average daily wastewater flow was estimated to be 186 gpd and the estimated wastewater loading to the infiltration area was 0.89 gpd/ft^2.

- The surficial groundwater flow direction is south-southwest at a gradient of 0.0027 feet/foot. Depth to groundwater at the site during this study ranged from approximately 1.5 to 5 feet bgs. Depths to groundwater in November, 1990 was 5 to 6 feet bgs.

- At the time of the highest measured groundwater levels (January 12, 1993), the thickness of unsaturated soil below the OSDS infiltration system was 0.34 feet.

- With the exception of the southeast corner of the property, the groundwater flow appears to have a very low vertical component. The vertical gradient at the nested set of monitoring wells in the southeast corner of the site is approximately the same as the horizontal groundwater gradient indicating groundwater in this area may move downward as it moves downgradient of the site.

- Grainsize analyses of soil samples obtained from boreholes at the site indicated that the soils were primarily composed of fine sand.

- The contaminant plume appears to have increased in horizontal extent since the last sampling event approximately 2 years ago and the total horizontal extent has not yet been defined. Concentrations of parameters indicative of STE were elevated above background levels in groundwater obtained from the six foot depth 25 feet downgradient of the OSDS.

- With the exception of nitrate-nitrogen, no evidence was observed that parameters characteristic of effluent had migrated below twelve feet bgs.

- The higher groundwater surface and the partial failure of the OSDS may have led to anoxic conditions beneath the infiltration area which, in turn, led to reduced nitrification at the site. As a result, ammonia nitrogen concentrations are elevated while nitrate-nitrogen concentrations are low. The concentrations of MBAS in groundwater downgradient of the system also suggested an anoxic environment. The higher groundwater table also appears to have reduced adsorption of phosphorus. Phosphorus concentrations in groundwater closest to the infiltration area were similar to the total phosphorus concentration of the STE.

- It is recommended that additional aquifer testing be conducted at the site to better define groundwater flow, and that groundwater monitoring be continued as the water table drops during the dry season. This will allow an evaluation of the effect of unsaturated thickness on treatment of the parameters of concern. Also, the complete horizontal extent of impacted groundwater should be determined, if possible, by adding additional downgradient sample points.

SECTION 6.0
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