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DATA REPORT
SEPTIC TANK LOADINGS TO LAKE TRAVIS AND LAKE AUSTIN

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TABLE OF CONTENTS

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The staff of the Lower Colorado River Authority was essential to the present study. H. M. Locker and Burt Carter provided guidance, support and coordination. Sample collection and laboratory analyses were supervised by Charles Dvorsky and Buck Henderson, respectively.

Several individuals at Espey, Huston & Associates, Inc. contributed to the project. Boyd Dreyer (formerly with the firm) and Jackson Harper served as project geologists, supervising the installation of monitoring wells, the compilation of data, and map preparation. Robin Miskell conducted many of the data analyses, including preparation of sampling data plots. Mapping and data analysis were also performed by Charles Montero. The principal investigator for the present study was James Miertschin.

1.0 INTRODUCTION

The present study of septic tank loadings involved compilation and analysis of land use, hydrologic, and geohydrologic data for the watersheds of Lakes Travis and Austin. The analysis focused upon those portions of the watersheds within 5,000 feet of the 681 MSL contour on Lake Travis and the 492.8 MSL contour on Lake Austin. A sampling program was conducted to determine typical pollutant loadings fron onsite wastewater systems. Constituent mass loadings to the reservoirs were calculated for existing and projected developmental conditions and compared to discharge alternatives.

The key objectives of the proposed study are summarized below:

1. delineate specific land use categories in the study area;
2. map areas with septic tank or similar onsite wastewater systems and with central systems;
3. map geologic, geohydrologic and hydrologic characteristics;
4. assess suitability for various disposal systems;
5. determine typical pollutant loadings from onsite systems;
6. estimate loads to reservoirs from onsite disposal systems;
7. project loads for future conditions and compare to treatment alternatives.

The preceding objectives constituted a comprehensive study of various aspects related to septic tank loadings in the study area. In particular, the study was designed to provide much needed site-specific data on potential pollutant loadings.

2.0 MAPPING

The present study included the preparation of several maps describing pertinent geologic and hydrologic characteristics in the study area. Each map described below is included in a map pocket accompanying the report.

Land Use

The land use map describes land use within a 5000-ft zone surrounding Lake Travis and Lake Austin. The following land use categories are identified: rural, urban with septic tanks, urban with centralized collection systems, and park/campgrounds.

Information for the land use map was obtained from the following sources:

1. In-house utility, subdivision, and land use data.
2. Municipal Utility District (MUD), Water District, and other development-oriented planning documents and plats on file with the City of Austin, Travis County and TDWR.
3. Interpretation of aerial photography.
4. Onsite surveys by EH&A personnel.

The land use information was recorded on U.S. Geological Survey (USGS) 7½-minute topographic maps.

Onsite Disposal Map

Urban land with septic tanks was identified on the preceding map. This land use category was further broken down into density categories on the onsite disposal map. The density categories were as follows: >2 acres per unit, >1 and ≤2 acres per unit, >½ and ≤1 acre per unit, and ≤½ acre per unit. The ">2 acres per unit" category was designated as rural with septic tank and the three remaining categories as urban with septic tank.

The data base used to develop the onsite disposal map consisted of the following:

1. In-house utility, subdivision, and land use data.
2. Municipal Utility District (MUD), Water District, and other development-oriented planning documents and plats on file with the City of Austin, Travis County, and TDWR.
3. Interpretation of aerial photography.
4. Onsite surveys by EH&A personnel.

The density information obtained for the onsite disposal map was recorded on USGS 7½ minute topographic maps for the 5000-ft study zone. Aerial photographs flown in December 1984 were used to delineate areas with significant onsite disposal density. The density categories were developed based upon the observed concentration of building units in developed areas, and do not necessarily reflect lot sizes. In effect, the categories define the observed density of onsite disposal systems based upon the observed density of building units. The areal estimates for each of the categories were obtained with a planimeter.

Disposal Suitablility Map

Available information about geology, surface soils, topography, and hydrology were used to derive a map that delineates the generalized suitability of land within the 5,000-foot study boundary for wastewater disposal via conventional onsite septic systems with soil absorption drainfield. Three categories were established for the purpose of mapping: very low suitability, low suitability, and moderate suitability.

Designation of an area as very low or low suitability does not preclude the use of onsite disposal systems, since systems can be designed for site-specific conditions. In addition, alternative wastewater disposal methods are available which may be more appropriate for some sites. Such methods include low-pressure dosing systems, mound systems, and evapotranspiration beds. Finally, the suitability of a given site for wastewater disposal is subject to other factors such as lot size, residential density, proximity of water wells, etc.

Information for the disposal suitability map was obtained from the following sources:

1. Garner, L. E. and K. P. Young. 1976. Environmental geology of the Austin area: An aid to urban planning. Univ. of Texas, Bureau of Economic Geology. Rept. of Investigations No. 86.
2. Rodda, P. U. 1970. Geology of the Austin West Quadrangle, Travis County, Texas. Univ. of Texas, Bureau of Economic Geology. Quadrangle Map No. 38.
3. U.S. Soil Conservation Service. Soil survey of Blanco and Burnet Counties, Texas. U.S. Department of Agriculture.
4. U.S. Soil Conservation Service. 1974. Soil survey of Travis County, Texas. U.S. Department of Agriculture.
5. Woodruff, Charles Marsh. 1973. Land-use limitations related to Geology in the Lake Travis vicinity, Travis and Burnet Counties, Texas. Dissertation, The Univ. of Texas.
6. Woodruff, C. M., Jr. 1975. Land capability in the Lake Travis vicinity, Texas; a practical guide for the use of geologic and engineering data. Univ. of Texas, Bureau of Economic Geology. Rept. of Investigations No. 84.

7. Woodruff, C.M., Jr., 1979. Land resource overview of the Capital Area Planning Council Region, Texas - a nontechnical guide. Univ. of Texas, Bureau of Economic Geology, Special Publication.

To evaluate the use potential of the multicounty area surrounding Austin, Texas for various human activities, Woodruff (1979) defined 24 "land resource units". Each resource unit exhibited a unique combination of surface and subsurface materials, surface landform, and hydrologic processes. Seven of the resource units occur within the 5,000 foot water quality zone. The identifying characteristics of each unit are outlined in Tables 2-1 and 2-2.

Depending on the conditions that are judged to have controlling influence on human activity, each land resource unit is defined to be a process unit or a material-landform unit. Process units are grouped into those dominated by either surface-water or ground-water conditions (i.e. recharge). Material-landform units are grouped into categories on the basis of substrate (e.g. limestone, unconsolidated sediments, claystone and sandstone) and topography (low to high relief).

The septic system suitability terminology used by Woodruff (1979) differs slightly from that used in this report. Herein, the suitability of the seven land resource units is categorized as very low, low, and moderate. The terms used by Woodruff included low, low to moderate, moderate, and moderate to high. The differences between the two catagorization schemes are relatively minor. Differences in the interpretation of septic system suitability were found in three instances, as explained below.

Woodruff (1979) interpreted the Karstic Limestone and Limestone Recharge Areas units as having low potential for septic system use. In this report, these two units are judged to have very low suitability for septic systems, in recognition of the sensitivity of these units to ground-water contamination via ground-water recharge.

Woodruff (1979) categorized the Claystone/Sandstone Uplands unit (Smithwick Formation) with a low potential for septic system use. This was apparently related to the low expected permeability of soils and substrate common to the resource unit, which could impair proper performance of conventional septic systems. In the present analysis, the Claystone/Sandstone Uplands were assumed to have moderate suitability, since proper septic system function can be achieved through adequate design, construction, and maintenance.

The Alluvium and Terrace Deposits unit was considered by Woodruff (1979) to have moderate to high potential for septic systems. Recognizing that some deposits exhibit very shallow water tables (less than 4 foot depth), the disposal suitability map of the present study classifies low-elevation areas adjacent to Lake Austin as having low suitability. It should also be recognized that the generalized mapping of this report and Woodruff (1979) cannot fully address the high degree of variability that can exist between different alluvium and terrace deposits.

Geology Maps

Two separate geology maps are included with this report. Surface and shallow subsurface geology within 5,000 feet of Lakes Travis and Austin is delineated on USGS 7½-minute base maps. Data for this map was obtained from the following sources:

1. Charles M. Woodruff, Jr. 1973. Published and unpublished mapping.
2. Rodda, P. V. et al. 1970. Geology of the Austin West Quadrangle, Travis County, Texas. Univ. of Texas, Bureau of Economic Geology. Quadrangle Map No. 38.

The surface and shallow subsurface geology within the Water Quality Areas of Lakes Travis and Austin (encompassing a 10-mile zone around the reservoirs) is presented on State Department of Highways and Public Transportation county highway maps (scale of 1 inch = 2 miles). Information for this geology map was derived from the following sources:

1. Barnes, Virgil. 1981. Geologic Atlas of Texas, Austin Sheet. Univ. of Texas, Bureau of Economic Geology.
2. Barnes, Virgil. 1981. Geologic Atlas of Texas, Llano Sheet. Univ. of Texas, Bureau of Economic Geology.
3. Garner, L. E. and K. P. Young. 1976. Environmental geology of the Austin area: An aid to urban planning. Univ. of Texas, Bureau of Economic Geology. Rept. of Investigations No. 86.

Soils Maps

The soils information is presented on two separate maps. Soils within 5,000 feet of Lakes Travis and Austin are identified on USGS 7½-minute topographic maps. Another map presents the general soil associations located within the 10-mile Water Quality Areas surrounding Lakes Travis and Austin. These soil associations are delineated on State Department of Highways and Public Transportation county highway maps (scale of 1 inch = 2 miles).

The data base used to develop the soils maps consisted of the following:

1. U.S. Soil Conservation Service. 1978. Soil survey of Blanco and Burnet Counties, Texas.
2. U.S. Soil Conservation Service. 1973. Soil survey of Hays County, Texas.
3. U.S. Soil Conservation Service. 1974. Soil survey of Travis County, Texas.

TABLE 2-1

LAND RESOURCE UNITS IN THE 5,000-FT WATER QUALITY AREA AND THEIR SUITABILITY FOR SEPTIC SYSTEMS

Land Resource Units				Generalized Capability for Septic System Use*
Group	Suite	Unit Code	Mappable Unit	
Process Units	Surface-Water Process Suite	P2	Valley Bottoms	Low Suitability
	Aquifer Suite	P3	Limestone Recharge Areas	Very Low Suitability
		P5	Mixed Rock Recharge Areas	Low Suitablity
Material-Landform Units	Surface Deposit Suite	M1	Alluvium and Terrace Deposits	Low to Moderate Suitability
	Limestone Suite	M7	Karstic Limestone	Very Low Suitability
		M9	High- to Moderate-Relief Alternating Beds of Limestone, Dolomite, and Marl	Low Suitability
	Claystone-Sandstone Suite	M12	Claystone/Shale Uplands	Moderate Suitability

* Categories slightly modified from original reference.

Source: Woodruff, 1979.

TABLE 2-2

MATERIAL, LANDFORM, AND PROCESS CHARACTERISTICS OF LAND RESOURCE UNITS IN THE 5,000-FT WATER QUALITY AREA

Unit Code	Materials		Landforms		Processes	Underlying Geologic Formation of Group
	Substrate	Soil	Slope/Relief	Morphology		
P2	Alluvial sand, gravel, and mud, locally admixed with colluvium; local bedrock may also be exposed	Clayey or loamy with common stony fraction (2 to 4 ft thick)	Mostly concave upward (1 to 2%); also local incised bluffs and dissected terraces; total relief up to 60 ft	Lowlands along minor stream courses	Flooding adjacent to streams; landsliding and soil creep along valley edges	Varies with location
P3	Limestone	Thin to absent (less than 2 ft thick) stony, clayey, or loamy soil	Gently sloping (2 to 5%) uplands; incised streams; relief 80-150 ft per square mile	Uplands pitted with sinkholes (karst topography); most recharge in adjacent stream bottoms (commonly mapped as flood-prone areas or Valley Bottoms	Recharge	Edwards, Ellenburger, Barnett Shale
P5	Sandstone and conglomerate with local limestone and shale	Sandy to clayey (more than 2 ft thick) on sandstones; thin, stony soils on limestone	5 to 8% slopes; average relief 130 ft per square mile	Rolling terrain; local bluffs	Recharge; slumping near bluffs; erosion and flooding along streams	Lower Glen Rose, Cow Creek, Hensell Hammet, Sycamore
M1	Alluvial sand, gravel, and mud	Mostly loamy, locally sandy or clayey (more than 4 ft thick)	Less than 5% slope; relief averages 20 ft per square mile	Nearly flat low-above flood plain	Local recharge; pondind in poorly drained areas	Varies with location
M7	Limestone; dolomite	Clayey or loamy (less than 2 ft thick)	Locally steep slopes (8 to 15%) with relief of 180 ft per square mile; also gently sloping (less than 8%) on karstic plains	Karstic uplands; dissected limestone	Sheetwash; rockfalls; local recharge	Marble Falls

TABLE 2-2 (Concluded)

Unit Code	Materials		Landforms		Processes	Underlying Geologic Formation of Group
	Substrate	Soil	Slope/Relief	Morphology		
M9	Resistant limestone and dolomite strata interbedded with erodible marl; local valley fill alluvium and colluvium	Thin to absent (less than 2 ft thick) clayey, loamy with common stony fraction	Slopes 8 to 15%; relief averages 250 ft per square mile; local areas as low as 100-150 ft per square mile	Stairstep topography	Erosion, some recharge in areas of low slope	Glen Rose Members 2 to 5 Walnut
M12	Claystone; shale; local lenses of resistant sandstone	Clayey (less than 2 ft thick)	5 to 8% slopes; relief 80 ft per square mile; local steep slopes along stream courses and where sandstone occurs	Discontinuous fault-bound areas of low relief	Erosion; slope failure in steep areas	Smithwick Formation

Source: Woodruff, 1979; with exception of designated geologic formations.

3.0 DATA COLLECTION ACTIVITIES

3.1 SAMPLING PROGRAM DESIGN

The sampling and data collection program was designed to determine typical pollutant loadings from onsite disposal systems. The sampling program encompassed both wet-weather and dry-weather conditions. The sampling program design was based primarily upon shallow ground-water monitoring to assess lateral effluent transport from individual septic systems.

At the outset of the study, septic systems in the study area that were candidates for monitoring were identified. Candidate sites were required to have appropriate geologic and topographic characteristics for monitoring. Sites could have been located virtually anywhere in the study area -- the proximity to the reservoirs, the residential density, or the population density were in reality not critical constraints, since the objective of the sampling program was to determine "typical" septic system loads, for extrapolation to the entire study area.

Shallow ground-water monitoring wells were installed at each test site. The placement of wells was dictated by the perceived direction of shallow ground-water flow. Three techniques were used to determine the direction of ground-water flow. First, the topography surrounding a test site was evaluated. In most cases, shallow ground-water flow was anticipated to conform to topographic constraints. At certain sites, visual observation of ground cover growth and color provided a second technique for identifying the drainfield plume area. Third, resistivity surveys were conducted by EH&A personnel in an effort to detect subsurface contaminant plumes or water tables. With these techniques, the direction of effluent travel from a drainfield was estimated to enable the installation of monitoring wells within the effluent plume.

The actual placement and configuration of monitoring wells was dictated by the specific conditions encountered at each test site. A series of single monitoring wells or sets of dual wells were anticipated at each test site. Initially, dual wells were planned -- one shallow (about 5-10 ft deep) and the other deep (about 15-20 ft deep). Well-pairs at different depths were envisioned to provide data on both the horizontal and vertical movement of leachate. A well-pair was also considered for location upgradient from the drainfield to characterize background conditions. Approximately three well-pairs were envisioned along an axis downgradient from the drainfield to characterize the leachate as it traveled through the subsurface soil. One of these well-pairs was to be installed adjacent to the drainfield to determine effluent characteristics of leachate exiting the drainfield. A shallow monitoring well was also prescribed within the drainfield itself. The distances between downgradient wells could vary as dictated by site-specific conditions. The anticipated typical positioning would be to locate the closest downgradient well-pair 1-2 ft from the drainfield, the second well-pair 10 ft from the drainfield, and the third well pair 50-60 ft from the drainfield. A hypothetical test site configuration is shown in Fig. 3-1. (The actual configurations of test site wells are described in Section 3.2.) EH&A supervised the installation of all monitoring wells. A local driller (Jack H. Holt and Associates, Inc.) was retained on a subcontract basis for construction of wells.

Borings were made with a 6-inch diameter auger. Well casing (or riser pipe) was 2-inch diameter PVC. Two-inch diameter slotted PVC screen was placed within the interval to be sampled, and the screen annulus was backfilled with clean sand. A layer of bentonite was placed in the annular space immediately above the sand pack. The remaining annulus was grouted with cement. Typical well construction features are displayed in Fig. 3-2.

3.2 TEST SITES

Test sites were selected to be generally representative of geologic, hydrologic, and topographic conditions in the study area. The following sections describe each site's physical setting and the monitoring network installed at each site. Completion specifications for all wells are given in Table 3-1.

Site No. 1

Site No. 1 was a residential septic system located near Lake Travis. System effluent is passed to absorption trenches which have been constructed on a gently sloping area. Absorption trenches at the site were originally installed several years before the study, but had been replaced approximately two years before the study commenced. The drainfield area was covered with stands of native grasses. The materials underlying the absorption area were found to consist of silty sands with some gravel. The materials appear to be relatively homogeneous, with the exception of a thin clay lens that was encountered at a depth of four feet during the installation of a monitoring well near the field. Another hole drilled adjacent to the first did not encounter the clay layer.

The site is located on a large Quaternary terrace deposit adjacent to Lake Travis, which overlies bedded limestone strata of the Cow Creek Formation. The thickness of the terrace is not known, since the maximum depth drilled at the site (15 feet) did not encounter bedrock.

Five wells were installed at the site to monitor water quality in and adjacent to the absorption area. Well locations are shown in Figure 3-3, and Figure 3-4 gives a profile view of the site. Well 1-4 (site number - well number) was completed at a depth of 2.35 feet in the drainfield. Wells 1-2 and 1-3 were installed to depths of 5 feet and 3.5 feet, respectively, downslope of the field. A 14.6-foot deep well (1-5) was also placed downslope of the field. Well 1-1 was positioned upslope of the field to provide background data.

Wells 1-2, 1-3, and 1-4 all encountered moist sediments during drilling, but only 1-3 and 1-4 produced water at completion. Wells 1-1 and 1-5 did not encounter any water or moisture during drilling.

Site No. 2

This residential site was located on uplands terrain in the general vicinity of Lake Travis, but removed from the lake. A grass cover was maintained on the drainfield area. The septic tank system had been in place approximately 11 years at the site. The site is underlain by bedded limestones of the Glen Rose Formation. A thin layer of sandy loam containing some cobble-size rock fragments is present at the surface. The rock strata encountered during well installation included soft and hard layers.

Five wells were installed at the site, as shown in Figures 3-5 and 3-6. Well 2-1 was drilled to a depth of 4.65 feet in the septic system's absorption field. Wells 2-2, 2-3, and 2-4 were installed at locations downgradient of the absorption field. Well 2-5 was installed approximately 50 feet from the field to serve as a background monitoring station. Wells 2-1 through 2-4 penetrated moist rock during installation, but produced no water immediately after completion. Well 2-5 encountered no discernible moisture during drilling, but did contain a small amount of water six days after completion. The distribution of saturated and partially saturated intervals may be indicative of absorption field effluent migrating along bedding planes.

Site No. 3

Site No. 3 was a residence located on a bluff that overlooks Lake Travis. Like Site No. 2, this site is underlain by the Glen Rose Formation, consisting of bedded limestone. The site area is relatively flat, but the surface does slope very gently toward the lake. The septic tank system at the site was approximately one-year old at the outset of the study. The drainfield area did not have a grass cover, but instead was relatively barren soil.

Five wells were drilled to depths ranging from 2.5 feet to 14.0 feet. The well locations and site plan are illustrated in Figure 3-7. A profile view of the site is provided in Figure 3-8. Well 3-1 was drilled to a depth of 2.5 feet in the absorption field. Wells 3-2, 3-3, and 3-4 were positioned at distances of 2 feet and 10 feet from the edge of the drainfield. Well 3-5 was located away from the field to provide background data for the site.

Wells 3-1, 3-2, and 3-3 produced small quantities of water following installation. Moist intervals were encountered in Well 3-4 during drilling, but no water could be produced immediately following well completion. Well 3-5 did not encounter any moisture during drilling and did not produce water on completion. The distribution of partially saturated zones at this site suggests that vertical migration of effluent may be occurring between the absorption field and the farthest downgradient monitoring well (3-4).

Site No. 4

Site No. 4 was a residence located in the uplands above Lake Austin. The septic system was approximately four years old when the study began. The drainfield was topped by a grass cover. The area is underlain by limestone strata of the Glen Rose Formation. The septic system absorption field has been installed near the toe of a moderate slope behind the residence. The site is underlain by bedded limestones of the Glen Rose Formation. Surface soils in the immediate vicinity of the absorption field consist of sandy loam with limestone rock fragments.

Five monitoring wells were installed at the location, as shown in Figure 3-9. A profile view of the site is provided in Figure 3-10. Well 4-2 was completed at a depth of 2.6 feet in the absorption field. Wells 4-3, 4-4, and 4-5 were installed at the toe of the slope in which the field was constructed. Well 4-1 was installed on the slope above the absorption field to provide background data for the monitoring program.

Wells 4-2 and 4-3 penetrated to saturated sediments during drilling and produced water upon completion. Wells 4-1 and 4-4 did not encounter any moist or saturated material in the intervals over which the wells were completed. Well 4-5 encountered a moist zone at a depth of about eight feet, but no water was produced following well completion.

Site No. 5

Site No. 5 was a residential septic system situated on an alluvial deposit adjacent to Lake Austin. Age of the system was approximately 15 years. The drainfield at the site is topped by a St. Augustine grass cover. A separate drainfield was in place at the site for disposal of laundry wastewater on an as-needed basis. The site is relatively flat and ground surface varies from 2-4 feet above the water surface elevation of the lake. The alluvial material consists of relatively homogeneous, slightly clayey silts. The ground-water table was encountered in all site borings at depths between three feet and four feet below ground level.

Five monitoring wells were installed at the locations shown in Figure 3-11. A profile of the site is included as Figure 3-12. Well 5-1 was completed in the absorption field at a depth of 2.15 feet. Wells 5-2, 5-3, and 5-4 were installed along a line between the field and the lake's edge at locations that were 2.5, 10.5, and 34 feet from the edge of the absorption field. Well 5-5 was installed at a distance of about 85 feet from the absorption field to serve as a background monitoring station for the site.

Site No. 6

Site No. 6 was located near Lake Travis and involves a septic system that serves 16 motel rooms. Daily occupancy of the motel wing varied from 0-32 persons. The absorption field is located in an area of flat ground adjacent to the motel. The site is underlain by soft and hard interbedded limestones of the Glen

Rose Formation. The surface is covered by a thin layer of sandy loam. A grass cover is maintained over the drainfield. The system was installed approximately seven years before the study.

Six monitoring wells were installed at the locations shown in Figure 3-13. Figure 3-14 provides a profile view of the site. Well 6-1 was completed to a depth of 2.75 in the absorption field. Approximately two feet from the edge of the field Wells 6-2 and 6-3 were installed at depths of 3.65 feet and 12.5 feet, respectively. Ten and one-half feet from the edge of the field, Wells 6-4 and 6-5 were completed at depths of 4.15 feet and 14.1 feet. Well 6-6 was installed about 50 feet from the field to provide background data for the site. All of the wells encountered water during drilling, and each well produced water after completion. The downgradient wells encountered two to three moist or saturated zones within 14 feet of the surface, which indicates that bedding planes may act as a flow path for lateral effluent migration. Therefore, vertical effluent migration is occurring in the vicinity of the field.

3.3 SAMPLING METHODOLOGY

Water quality samples were collected from the wells at approximately monthly intervals, with the sampling program extending over a 10-month period. Samples were analyzed for chloride, total phosphorus, orthophosphate phosphorus, organic nitrogen, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, biochemical oxygen demand (5-day), and fecal coliform bacteria.

On each sampling survey, one ground-water sample was collected from each monitoring well that contained water. Prior to sample collection, wells were pumped to ensure that representative samples were collected. Sterile sampling techniques were employed to minimize extraneous bacteriological contamination. The monitoring wells were sampled with a peristaltic pump, using sterilized tubing and sample containers. To collect a sample, the pump intake was lowered to the screened interval within each well. Prior to each survey, the plastic tubing was packaged and sterilized by autoclaving in the laboratory to prevent contamination. A separate length of tubing was prepared for each monitoring well to avoid cross-contamination. Sampling personnel were outfitted with rubber or plastic gloves and a supply of chlorine solution was maintained with the field crew for use as an onsite disinfectant.

At one test site near Lake Austin, water samples were collected from the adjacent cove for evidence of septic tank loadings. In most cases, the volume of dilution water provided by a reservoir would prevent the detection of effects from isolated drainfields. However, coves or embayments surrounded by densely-spaced septic tank systems could possibly exhibit measurable water quality impacts. Since the depth of the cove was relatively shallow, a surface layer sample was collected on each monitoring survey.

Sample collection, handling and analytical techniques conformed to recommended EPA or American Public Health Association methodology. Chemical preservatives were employed for certain constituents, and appropriate sample containers were utilized, as per EPA recommendations. Following the addition of chemical preservatives, all containers were refrigerated and transported to the LCRA laboratory in Austin.

3.4 SAMPLING RESULTS

This section presents a qualitative and quantitative description of the monitoring well data collected in the present study. Data are presented for each test site separately, and the discussion of each site begins with a summary of the sampling program conducted at that location, including numbers of samples collected and specific data gaps. This information is tabulated for all sampling stations and sites in Appendix A. Next, a brief description of the behavior of each water quality constituent is given. Summary statistics and observed water-quality trends are included. The results of all laboratory analyses performed during the project are presented in Tables A-1 through A-6 in Appendix A.

Site No. 1

Of a maximum of 50 possible samples from Site No. 1, 31 (62%) were collected. Of the 279 analytical tests potentially available from these samples, 221 (79%) were actually performed. Data gaps at the site are principally the result of the lack of samples from Wells 1-1 and 1-5. Well 1-5 produced no samples during that project, and Well 1-1 yielded only three. Sample volumes from Well 1-1 were generally small, and only one was sufficient for the analysis of all parameters.

Wells 1-2, 1-3, and 1-4 produced relatively complete data sets. With the exception of Well 1-2 in September, a sample was collected at each station every month. Missing analytical data from these wells are attributable to limited sample volumes. In addition, the presence of Rhodamine-WT (dye tracer) in Well 1-4 interfered (colorimetrically) with most analyses in the April sample.

As previously described in Section 3.2, the materials underlying the site are composed of a relatively homogeneous mixture of silt, sand, pebbles, and cobbles. The laterally discontinuous clay layer encountered in Well 1-2 may extend beneath Well 1-3 and create a perched water table. The consistent availability of samples from Wells 1-4, 1-3, and 1-2 tends to support this hypothesis.

Biochemical oxygen demand (BOD) values measured at the site ranged from 2 - 25 mg/l and averaged 10 mg/l. Although the number of available analyses from Wells 1-4 and 1-2 is limited, the mean values of BOD show a decrease with increasing distance from the absorption field. The mean values encountered in Wells 1-4, 1-3, and 1-2 were 12, 9, and 7 mg/l, respectively.

Chloride concentrations varied from 49-253 mg/l and averaged 103 mg/l. The lowest value occurred in the absorption field (Well 1-4) and the highest in

Well 1-2. Mean chloride concentrations were observed to increase successively in Wells 1-3 and 1-2. Mean values of chloride in Wells 1-4, 1-3, and 1-2 were 88, 92, and 198 mg/l, respectively.

Fecal coliform counts ranged from 0-48,400/100 ml at Site No. 1. The ranges measured in Wells 1-4 and 1-3 were similar; 9-48,400/100 ml and 18-48,400/100 ml, respectively. Mean values for Well 1-3 were greater than those in Well 1-4, however. Fecal coliform counts in Well 1-2 averaged only 9/100 ml.

Ammonia nitrogen concentrations varied from a low of 0.01 mg/l in Well 1-2 to a high of 11.90 mg/l in Well 1-3. The mean value for the site was 3.38 mg/l. Samples from Well 1-4 had an average ammonia concentration of 3.10 mg/l. Ammonia levels increased in Well 1-3, to a mean value of 6.57 mg/l. Concentrations in Well 1-2 were considerably lower and averaged 0.08 mg/l.

Organic nitrogen values at the site showed relatively little variation among wells. The levels reported from Well 1-4 in the absorption field were slightly higher than those from the downgradient wells and averaged 1.34 mg/l. Concentrations in downgradient Well 1-3 averaged 1.00 mg/l. The levels in Well 1-2 averaged 1.09 mg/l.

Nitrate nitrogen analyses produced numbers that ranged from 0.01 mg/l in Well 1-3 to 13.40 mg/l in background Well 1-1. The average nitrate value at the site was 4.85 mg/l. Like organic nitrogen, nitrate showed a decrease in its mean from Well 1-4 (6.32 mg/l) to Well 1-3 (3.47 mg/l) and increase from Well 1-3 to Well 1-2 (4.48 mg/l).

Nitrite nitrogen concentrations ranged from 0.01-0.33 mg/l and averaged 0.06 mg/l. Levels in Wells 1-4, 1-3, and 1-2 showed very little variation in their minimum, maximum and mean values and no distinctive data trends were noted.

Orthophosphate phosphorus at the site varied from 0.003 mg/l in Well 1-2 to a high of 3.83 mg/l in Well 1-4 and averaged 1.16 mg/l. Levels were observed to decrease from Well 1-4 to Well 1-3 to Well 1-2. Mean values for Wells 1-4, 1-3 and 1-2 were 2.490, 0.950, and 0.045 mg/l, respectively.

Total phosphorus analyses ranged from 0.029 mg/l in Well 1-2 to 6.240 mg/l in Well 1-4. The mean value was found to be 1.435 mg/l. Total phosphorus behavior was similar to that of orthophosphate phosphorus. Mean concentrations decreased steadily from 3.184 mg/l in Well 1-4 to 1.110 mg/l in Well 1-3 to 0.099 mg/l in Well 1-2.

Until this point, the analytical data for Well 1-1 (background well) has not been addressed. In general, the limited number of analyses from Well 1-1 show the concentrations for all parameters to be very similar to those found in the absorption trenches (Well 1-4) or the closest downgradient well (Well 1-3). This may indicate naturally occurring conditions, or it may suggest contamination from the drainfield or another unrecognized source.

In conclusion, the behavior of several constituents suggests that effluent flow is intercepted by Wells 1-3 and 1-2 at increasing distances from the drainfield. Examination of the data shows that chloride and nitrate values in Well 1-4 are slightly lower than or equal to those in Well 1-3, and concentrations in Well 1-2 are higher than those in Well 1-3. On the other hand, ammonia nitrogen, organic nitrogen, orthophosphate phosphorus, and total phosphorus concentrations generally decrease towards Well 1-2 from Well 1-4. These trends are examined in greater detail in Section 4.2.

Site No. 2

Five monitoring wells at Site No. 2 were sampled monthly over a ten-month period. Of the 50 samples potentially available, 27 (54%) were collected. Of the potential 243 analytical values avaiable, 139 (57%) were obtained. Sample availability was limited at Wells 2-2, 2-3, 2-4, and 2-5.

Samples were collected from the absorption field (Well 2-1) each month. Except for three samples, for which only fecal coliform counts were made, the data set for Well 2-1 is complete.

Downgradient Well 2-3 and background Well 2-5 were dry during most of the project and produced practically no data. One fecal coliform count was obtained from Well 2-3 in October. Three fecal coliform counts were available from Well 2-5.

Downgradient Wells 2-2 and 2-4 were sampled five and eight times, respectively, but provided only partial data sets. Only three samples from Well 2-2 were analyzed for more than fecal coliform.

BOD values in the absorption field ranged from 8-41 mg/l and averaged 24 mg/l. The single BOD value from Well 2-2, located two feet downgradient of the field, was 10 mg/l. Values in Well 2-4, located eight feet from the field, were 6 and 8 mg/l.

Chloride levels in Well 2-1 varied from 23-69 mg/l and averaged 36 mg/l. The two chloride values from downgradient Wells 2-2 and 2-4 were 8 mg/l and 30 mg/l, respectively.

Fecal coliform counts at the site ranged from 10/100 ml to more than 150,000/100 ml. The counts in the absorption field (Well 2-1) and the nearest downgradient well (Well 2-2) averaged about 24,700/100 ml and 49,800/100 ml, respectively. The counts from downgradient Well 2-4 were always less than 100/100 ml, with the exception of the first sample (September), which had a count of 94,000/100 ml. The sole fecal coliform count from downgradient Well 2-3 in October was 10/100 ml.

Ammonia concentrations at the site ranged from <0.01 to 41.40 mg/l. Values in the absorption field averaged 36.55 mg/l. Concentrations in downgradient Wells 2-2 and 2-4 were much lower; with mean values of 1.47 mg/l and 2.01, respectively.

Organic nitrogen levels in the absorption field ranged from 0.16-3.10 mg/l and average 0.91 mg/l. The mean concentration in Well 2-2 was 4.06 mg/l. At Well 2-4, the levels averaged 3.03 mg/l.

Nitrate concentrations at Wells 2-1 and 2-4 were unusually high (16.05-44.00 mg/l) in October and November, compared to subsequent months. The high values obscure an otherwise distinct trend of increasing concentration with increasing distance from the absorption field. Mean values in Wells 2-1, 2-2, and 2-4 were 0.16, 0.26, and 2.26 mg/l, after excluding the high values.

Nitrite analyses were available on a regular basis from Well 2-1 only . Levels encountered at Well 2-1 varied from 0.02-2.33 mg/l and averaged 0.49 mg/l. Removal of the sole high value, however, results in a mean concentration of 0.12 mg/l. Single analyses from Wells 2-2 and 2-4 were 0.16 mg/L and <0.01 mg/l, respectively.

Orthophosphate ranged from 0.457-6.550 mg/l and averaged 4.497 in Well 2-1. The low value is one order of magnitude less than the other samples, and its removal results in a mean value of 5.17 mg/l. Levels in Well 2-2 ranged from 0.327-0.652 mg/l. In Well 2-4, the mean value was 0.300 mg/l.

Total phosphorus concentrations behaved similarly to orthosphosphate. The levels exhibited a distinct decrease with increasing distance from the site. Mean levels in Wells 2-1, 2-2, and 2-4 were 5.077, 0.826, and 0.351 mg/l, respectively.

In conclusion, BOD, orthosphate, and total phosphorus concentrations decreased in the wells downgradient of the absorption field. Organic nitrogen and nitrate levels increased. No clear trends were observed for chloride, fecal coliform, and nitrite.

Site No. 3

Thirty-three samples were collected from the five monitoring wells at Site No. 3 during ten months of sampling. Out of 297 possible analytical values from the samples, 117 (39%) were determined. Dry conditions in Wells 3-3 and 3-5 were the principal cause of the lack of data. Incomplete analyses of samples from Wells 3-1, 3-2, and 3-4 occurred, as a result of small available sample volumes. Complete fecal coliform data sets are available for Wells 3-1, 3-2, and 3-4. Data sets are relatively complete for ammonia, organic nitrogen, nitrate, orthophosphate, and total phosphorus from Wells 3-1 and 3-2.

Only five BOD measurements were obtained over the ten-month sampling program; one each, from Wells 3-2, 3-3, and 3-4 and two from Well 3-1. Values ranged from 9-27 mg/l and averaged 18 mg/l. Levels in the absorption field (Well 3-1) were 25 mg/l and 27 mg/l.

Chloride data is also minimal for the site. Only three values were determined; one each for Wells 3-1, 3-2, and 3-4. In the absorption field (Well 3-1), chloride was found to be 104 mg/l in June. In the same month, the values in downgradient Wells 3-2 and 3-4 were 96 mg/l and 50 mg/l.

Fecal coliform data is complete for the absorption field (Well 3-1) and the two shallow downgradient wells (3-2 and 3-4). Two analyses are available for the deep downgradient well (3-3). Fecal coliform counts in the absorption field were less than 30/100 ml, with the exception of one count of 1850/100 ml. Values in the shallow downgradient Well 3-2 were slightly greater; ranging from 0/100 ml to

220/100 ml. Counts in Wells 3-3 and 3-4 were significantly greater, 49,800 and 27,300/100 ml, respectively.

Ammonia concentrations in the absorption field varied from 1.96-23.00 mg/l and averaged 12.33 mg/l. Levels decreased sharply in downgradient Wells 3-2 and 3-4, where mean concentrations were 0.07 mg/l and 0.17 mg/l. The one value from Well 3-3 was 0.44 mg/l.

Organic nitrogen levels in the absorption field varied from 0.5-20.74 mg/l and averaged 6.46 mg/l. Removal of the highest value produces a mean value of 2.88 mg/l. Mean levels in downgradient Wells 3-2 and 3-4 were not significantly different; 1.45 mg/l and 2.13 mg/l, respectively.

Nitrate values in the absorption field ranged from 6.59-33.80 mg/l, although most values were greater than 15 mg/l. Well 3-2 produced one anomalously low value as well, with the majority of values falling between 10.10 mg/l and 18.85 mg/l. The two values reported for Well 3-4 were 32.90 mg/l and 35.47 mg/l. No trends were evident.

Insufficient nitrite data were available to define a behavioral pattern. Concentrations in the absorption field were the highest reported (0.31-9.94 mg/l), while the levels in downgradient wells were less than 0.2 mg/l.

Orthophosphate concentrations in Well 3-1 ranged from 1.530 mg/l to 12.100 mg/l and averaged 8.256 mg/l. Four feet from the absorption field, the levels dropped sharply and ranged from <0.001-0.712 mg/l. Eight feet from the field, at Well 3-4, the levels increased slightly. Total phosphorus behaved similarly.

The data from Site No. 3 revealed no strong trends. Concentrations of most constituents (ammonia, organic nitrogen, nitrite, orthophosphate, and total phosphorus) were significantly lower in downgradient Well 3-2 than in the absorption field, however.

Site No. 4

The five wells installed at Site No. 4 yielded 25 samples over the ten-month sampling period. Out of potential 225 analytical tests, 189 (84%) were obtained. Relatively complete data sets were available for the absorption field well (4-1) and downgradient Well 4-4. No samples could be obtained from Well 4-3, and only three fecal coliform counts were obtained from Well 4-5.

BOD values in the absorption field ranged from 5-25 mg/l and averaged 17 mg/l. Downgradient Well 4-4 exhibited consistently lower values (1-15 mg/l)), with an average of 6 mg/l. Levels in the background well (4-1) were usually similar to those in the absorption field.

Chloride concentrations in the absorption field ranged from 38-195 mg/l and averaged 86 mg/l. The background well (4-1) exhibited similar concentrations. Downgradient Well 4-4 had values that were slightly greater than the drainfield, 75-161 mg/l.

Fecal coliform counts at the site showed relatively little variation, as compared to the other sites. Except for a few anomalously high values, fecal coliform counts were less than 100/100 ml.

Ammonia values in the absorption field did not vary widely (1.01-8.21 mg/l) and averaged 4.58. Levels in downgradient Well 4-4 were much lower, averaging 0.95 mg/l.

Organic nitrogen levels in site wells showed relatively little variation. Samples from Well 4-1 averaged 2.12 mg/l. Levels in Well 4-2 averaged 1.48 mg/l. Those in Well 4-4 averaged about 1.56 mg/l.

Nitrate levels were lowest in the absorption field (Well 2-1), where they averaged 0.36 mg/l. Both Well 4-1 and 4-4 exhibited greater value; 3.50 mg/l and 12.75, respectively. Nitrite values, however, showed comparatively little change among wells.

Orthophosphate and total phophorus concentrations exhibited similar behavior at most sites; concentrations at locations away from the absorption field were lower than concentrations in the field. Orthophosphate averaged 1.782 mg/l at Well 4-2 and 0.062 mg/l at Well 4-4. Total phosphorus at Well 4-2 averaged 2.205 mg/l, with mean value of 0.103 mg/l at Well 4-4.

Although the amount of data from downgradient wells and the background well at Site No. 4 is rather limited, certain trends occurring at other sites seemed to hold true at Site No. 4. BOD, ammonia, orthophosphate, and total phosphorus decreased downgradient of the absorption field, while chloride and nitrate levels increased.

Site No. 5

Water-quality samples were collected from five monitoring wells at Site No. 5. In addition, one surface-water station (5-6) was sampled for nine months. The chemical data set for this site is very complete compared to the sites previously described. Fifty-eight out of fifty-nine possible samples were collected (98%), and 497 analytical tests out of a possible 522 (95%) were obtained.

BOD concentrations were observed to be highest in the absorption field (Well 5-1) and lower in progressively more distant downgradient Wells 5-2 and 5-3. Average BOD values in Wells 5-1, 5-2, and 5-3 were 68, 40, and 13 mg/l, respectively.

Chloride values in the drain field and the first downgradient well were approximately the same; 107 mg/l at Well 5-2 versus 119 mg/l at Well 5-1. Between

Wells 5-2 and 5-3, concentrations increased to a mean of 175 mg/l. Concentrations in Wells 5-4 and 5-5 were even higher, with mean values of 196 mg/l and 313 mg/l, respectively.

Fecal coliform counts at the site varied from a low of 8/100 ml to 600,000/100 ml. Despite the wide range encountered in most wells, minimum, maximum and mean values suggested a trend of increasingly greater counts with increased distance from the absorption field. Mean fecal coliform counts in Wells 5-1 through 5-4 were about 48,400, 102,500, 106,200, and 141,400/100 ml, respectively.

Ammonia concentrations also decreased downgradient of the absorption field. After removing unusually high and low values, mean values encountered at Wells 5-1, 5-2, and 5-3 were 50.62, 33.72, and 0.58 mg/l. The value in Well 5-4 was slightly higher than Well 5-3. Background Well 5-5 had a mean value of 0.49 mg/l, which is very close to the level found in Well 5-3.

Organic nitrogen displayed a tendency to decrease with distance from the absorption field. Average values in Well 5-1 were 3.00 mg/l. In Well 5-2, they dropped to a mean of 2.03 mg/l. In Well 5-3, levels were about 1.65, and in Well 5-4 they averaged 1.59. (Abnormally high values in the June samples from Wells 5-3 and 5-4 were excluded from these averages.)

Nitrate levels varied from <0.01 mg/l to 2.76 mg/l but were typically less than 1 mg/l in all wells. Differences among the well values were judged to be relatively minor. Nitrite data showed very similar behavior to nitrate. Nitrite values were commonly very low (<0.5 mg/l), and little variation among the wells was observed.

Both orthophosphate and total phosphorus exhibited decreasing concentrations downgradient of the absorption field. Mean values of orthophosphate in

Wells 5-1, 5-2, and 5-3 were 11.663, 0.921, and 0.346 mg/l, respectively. The level in Well 5-4 averaged 0.042 mg/l. Background Well 5-5 had a mean concentration of 0.399 mg/l. Mean total phosphorus concentrations in Wells 5-1, 5-2, and 5-3 were 12.485, 1.306, and 0.253 mg/l. The average value in Well 5-4 was 0.31 mg/l.

Site No. 6

Six monitoring wells were installed at Site No. 6 and sampled monthly for a period of 10 months. Fifty-nine (98%) out of a potential 60 samples were collected. Of the 531 analytical tests potentially available, 508 (96%) were conducted. The set of data that exists for Site No. 6 is nearly complete. One sample was not collected from Well 6-3 in the month of December. A few samples from Wells 6-1, 6-2, 6-3, and 6-4 were inadequate in volume for complete analytical testing.

BOD concentration at the site varied from 1-110 mg/l and had an average value of 11 mg/l. Concentrations in the absorption field averaged 12 mg/l and those in the nearest shallow downgradient well (6-2) exhibited approximately the same range and a mean value of 13 mg/l. Downgradient Wells 6-3 and 6-4 had mean values that were less than those in Wells 6-1 and 6-2. One anomalously high BOD value (110 mg/l) in Well 6-5 raised that well's average concentration above the remaining wells. In general, BOD concentrations were found to decrease with distance from the absorption field.

Chloride concentrations in the absorption field averaged 378 mg/l. Wells 6-2 and 6-3, which are located approximately two feet from the field, exhibited mean chloride concentrations of 581 and 1,338 mg/l, respectively. Ten feet from the field, concentrations in Wells 6-4 and 6-5 were 586 and 139 mg/l. Concentrations in the background well (6-6) averaged 237 mg/l. Although an increase in chloride levels at distances away from the field is suggested, the trend is not well defined.

Fecal coliform counts in the absorption field varied from 2 to 3,280/100 ml and averaged 661/100 ml. The mean counts in all downgradient wells, except Well 6-5, were under 100/100 ml. Anomalously high counts in the samples collected in May and June from Well 6-5 raised the average value from about 8/100 ml to more than 123,000/100 ml.

Ammonia nitrogen values also suggest a decreasing trend with distance from the absorption field. Measured values in the absorption field and Well 6-2 averaged about 1.4 mg/l each. Except for Well 6-3, the downgradient wells had average values less than 1.0 mg/l.

Organic nitrogen concentrations in the absorption field and in the first shallow downgradient well averaged 1.15 and 1.05 mg/l, respectively. All other wells had average values from 0.69-0.90 mg/l. Levels in background Well 6-6 averaged 0.82 mg/l. No definitive trend was identified.

Nitrate levels in Well 6-1 averaged 0.79 mg/l and increased to 2.49 mg/l and 4.49 mg/l in downgradient Wells 6-2 and 6-4, respectively. Mean levels in downgradient Wells 6-3 and 6-5, 0.13 mg/l and 0.06 mg/l, respectively, were less than those in the absorption field. Background Well 6-6 had a mean value of 0.67 mg/l.

Nitrite concentrations ranged from <0.01 to 3.07 at the site. The highest concentration was encountered in downgradient Well 6-3. The next highest value was 0.87 mg/l in Well 6-3. Most reported values were less than 0.5 mg/l.

Both orthophosphate and total phosphorus had their greatest concentrations in the absorption field, with averages of 0.336 mg/l and 0.433 mg/l, respectively. Levels in Well 6-2 were similar. Concentrations were found to be lower in the remaining downgradient wells, but the differences were not large. Concentrations in the background well were comparable to those in the downgradient wells.

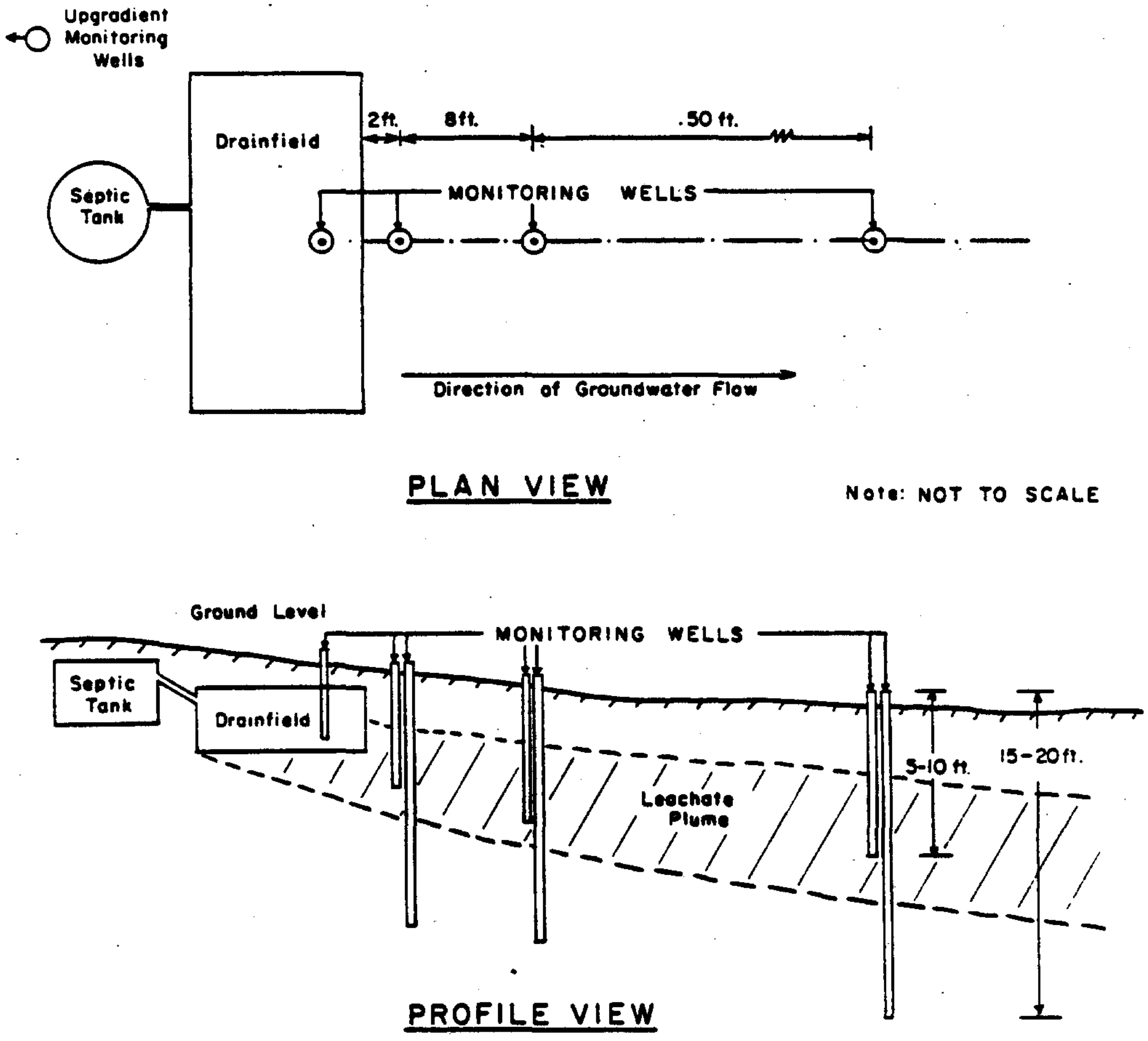

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Fig. 3-1

Hypothetical Test Site

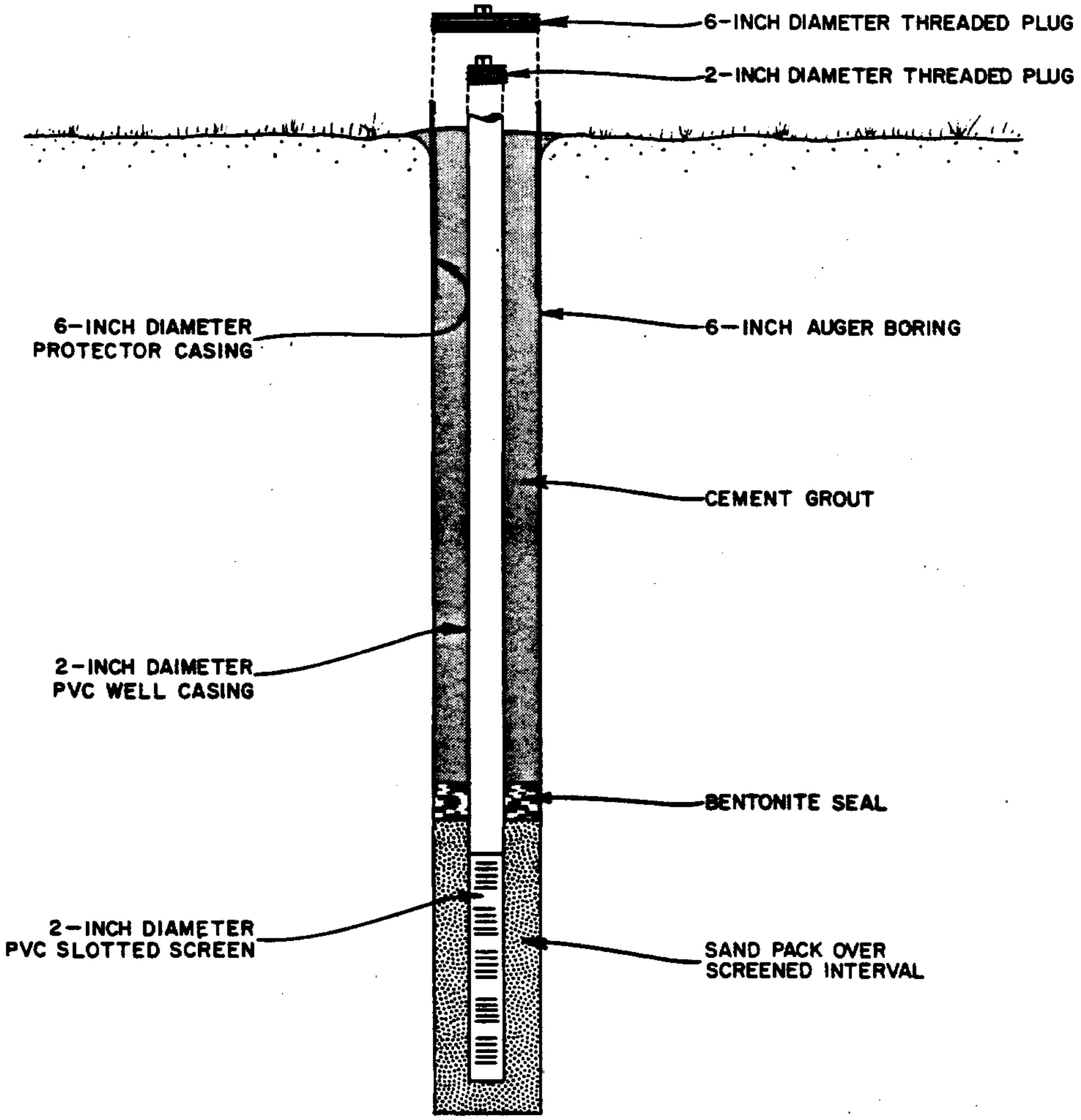

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Fig. 3-2

Typical Monitor Well

Construction

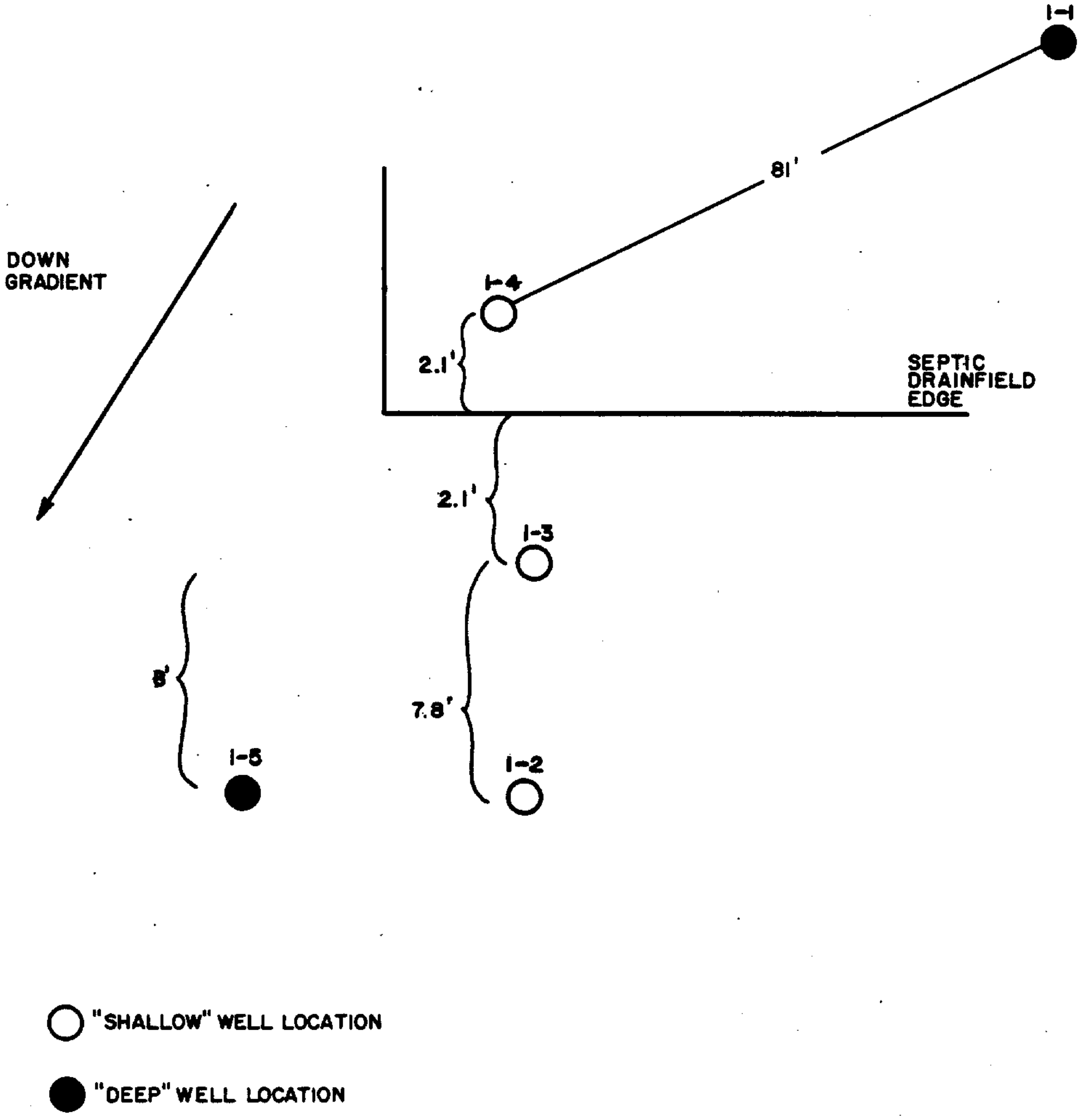

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Fig. 3-3
Plan View
Site No. 1

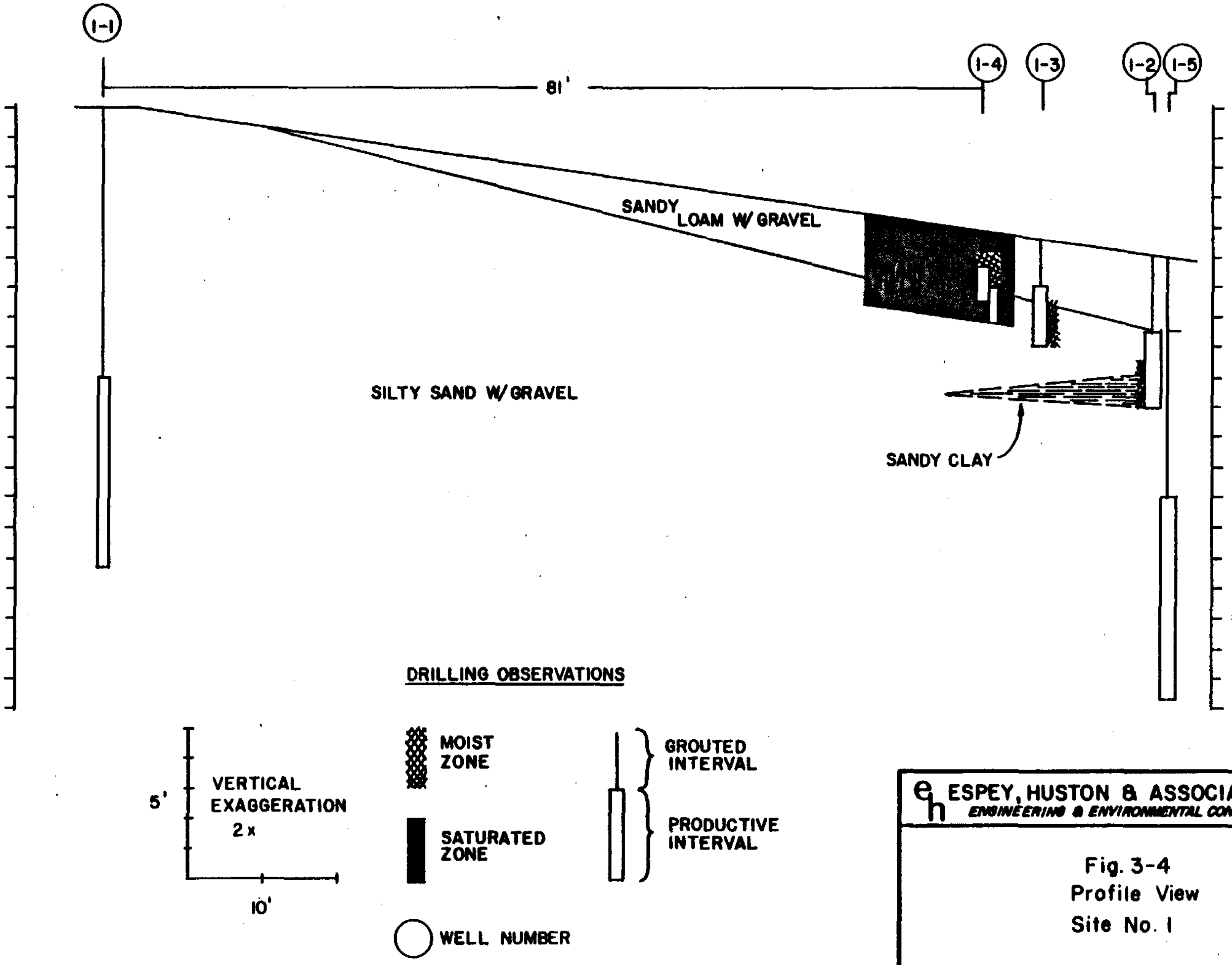

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Fig. 3-4
Profile View
Site No. 1

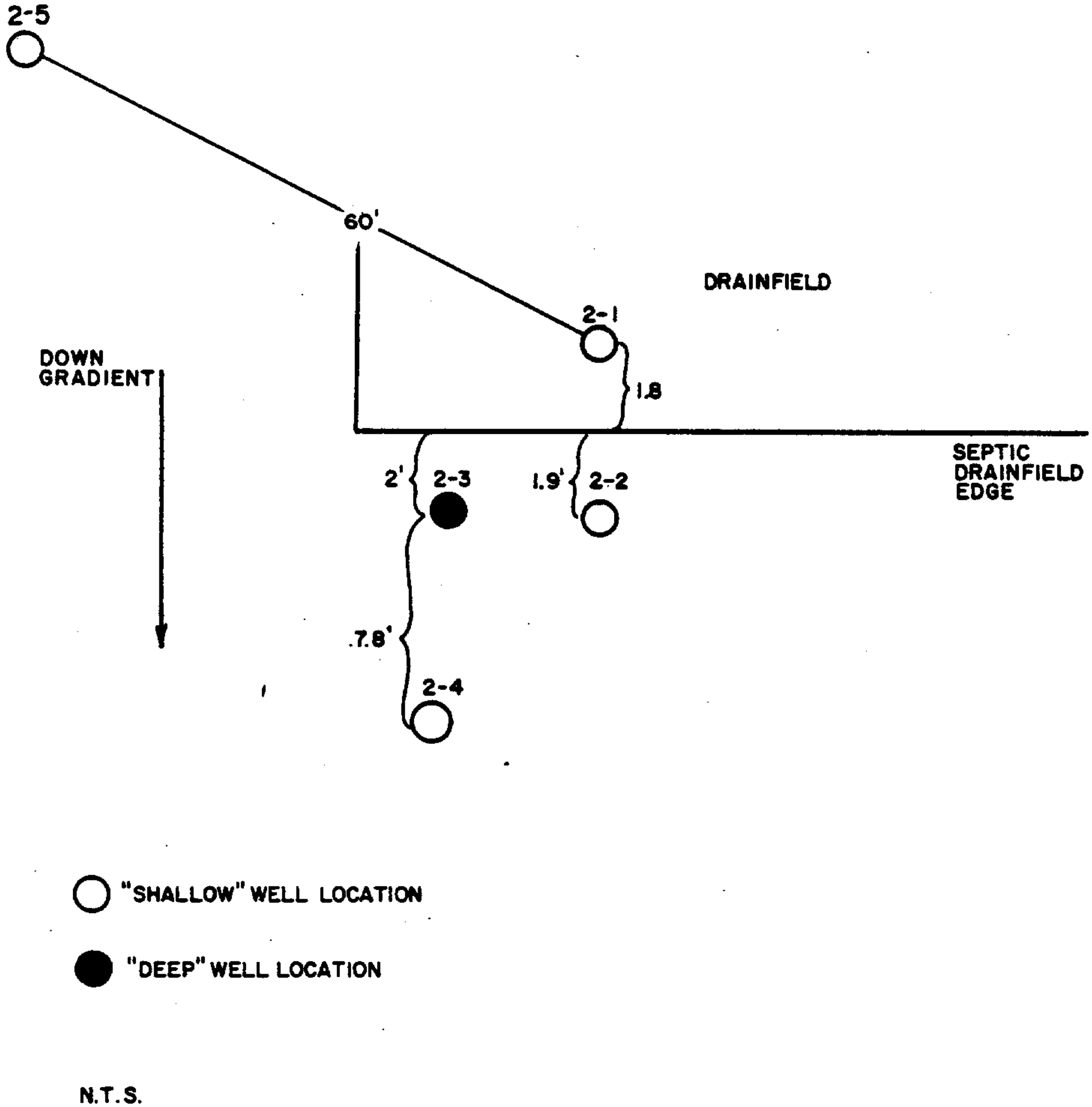

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Fig. 3-5
Plan View
Site No. 2

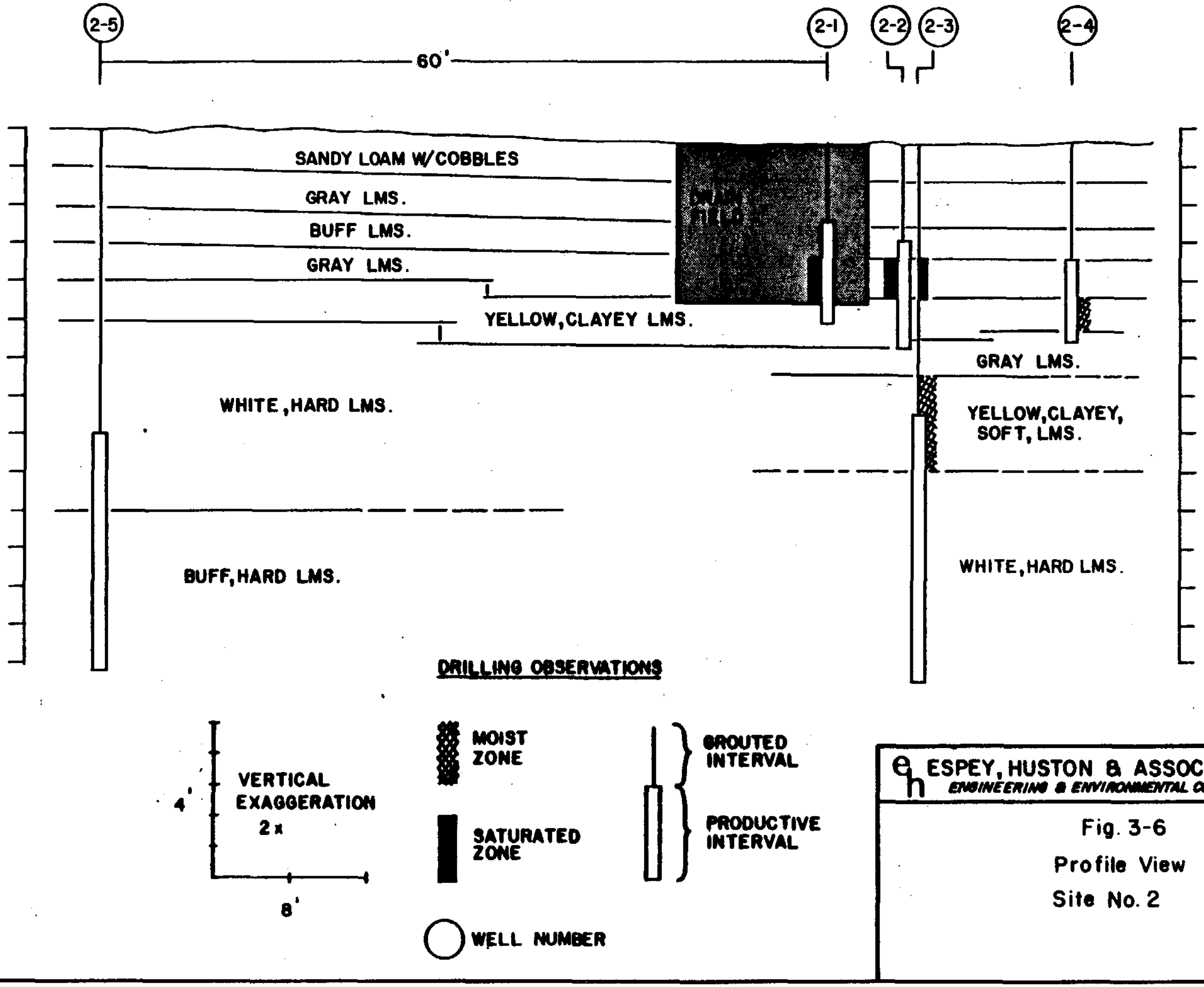

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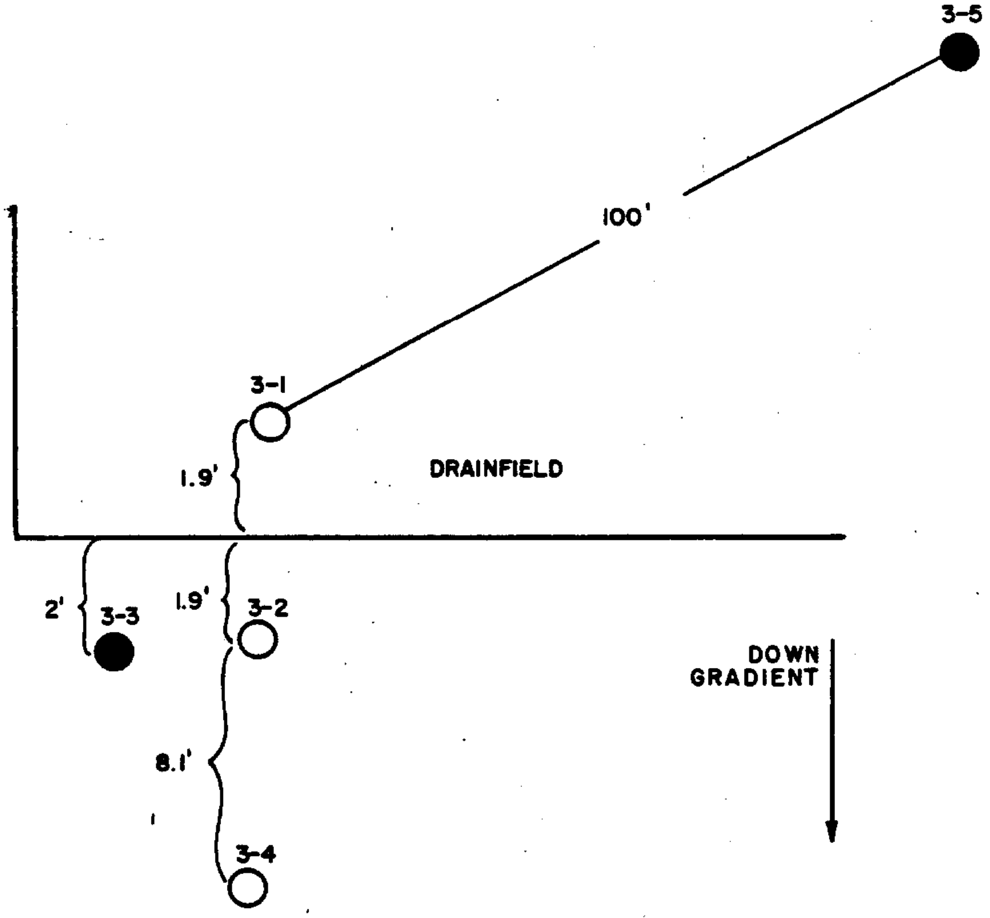
Fig. 3-6
Profile View
Site No. 2



○ "SHALLOW" WELL LOCATION

● "DEEP" WELL LOCATION

N.T.S.

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Fig 3-7
Plan View
Site No. 3

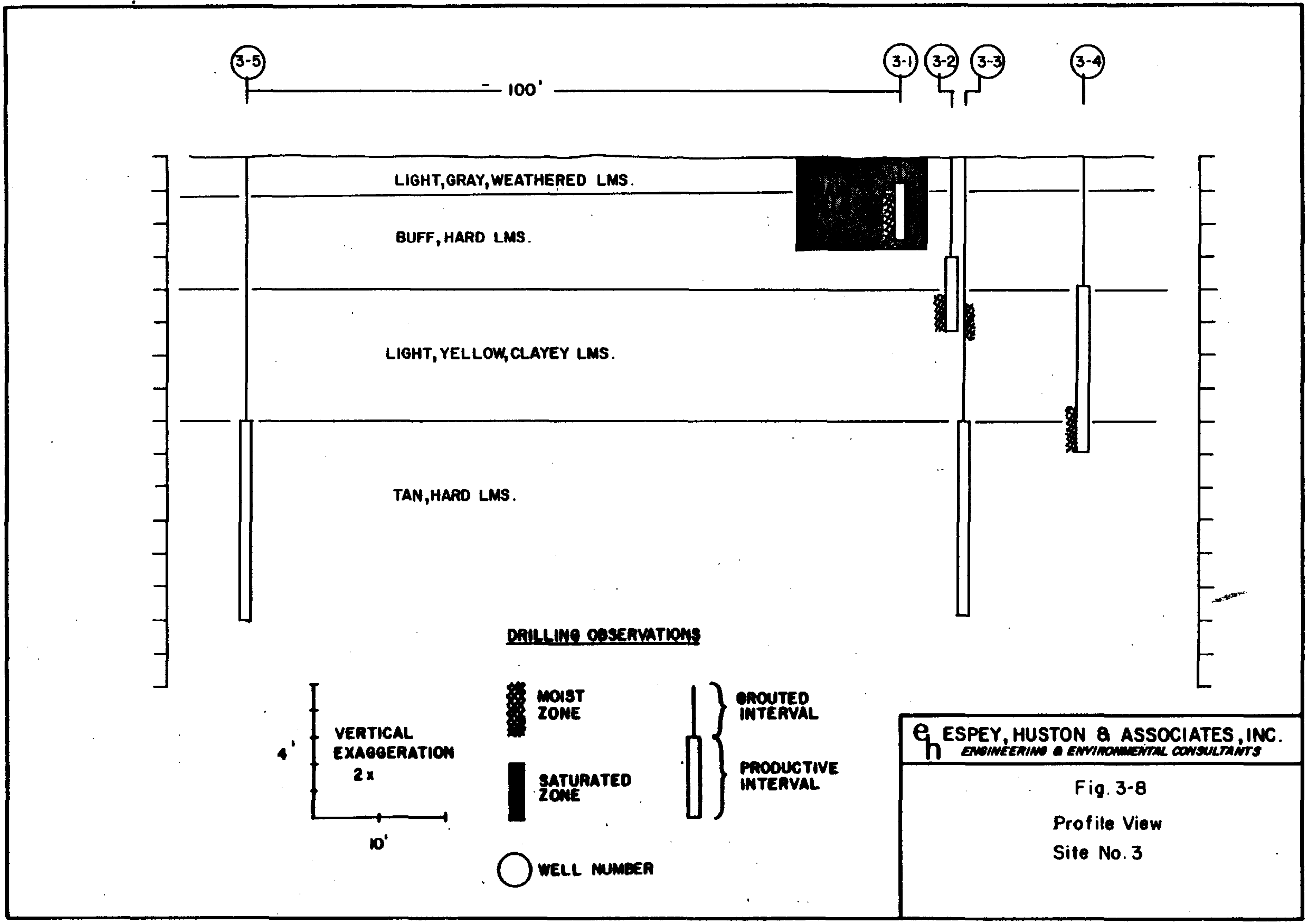

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Fig. 3-8
Profile View
Site No. 3

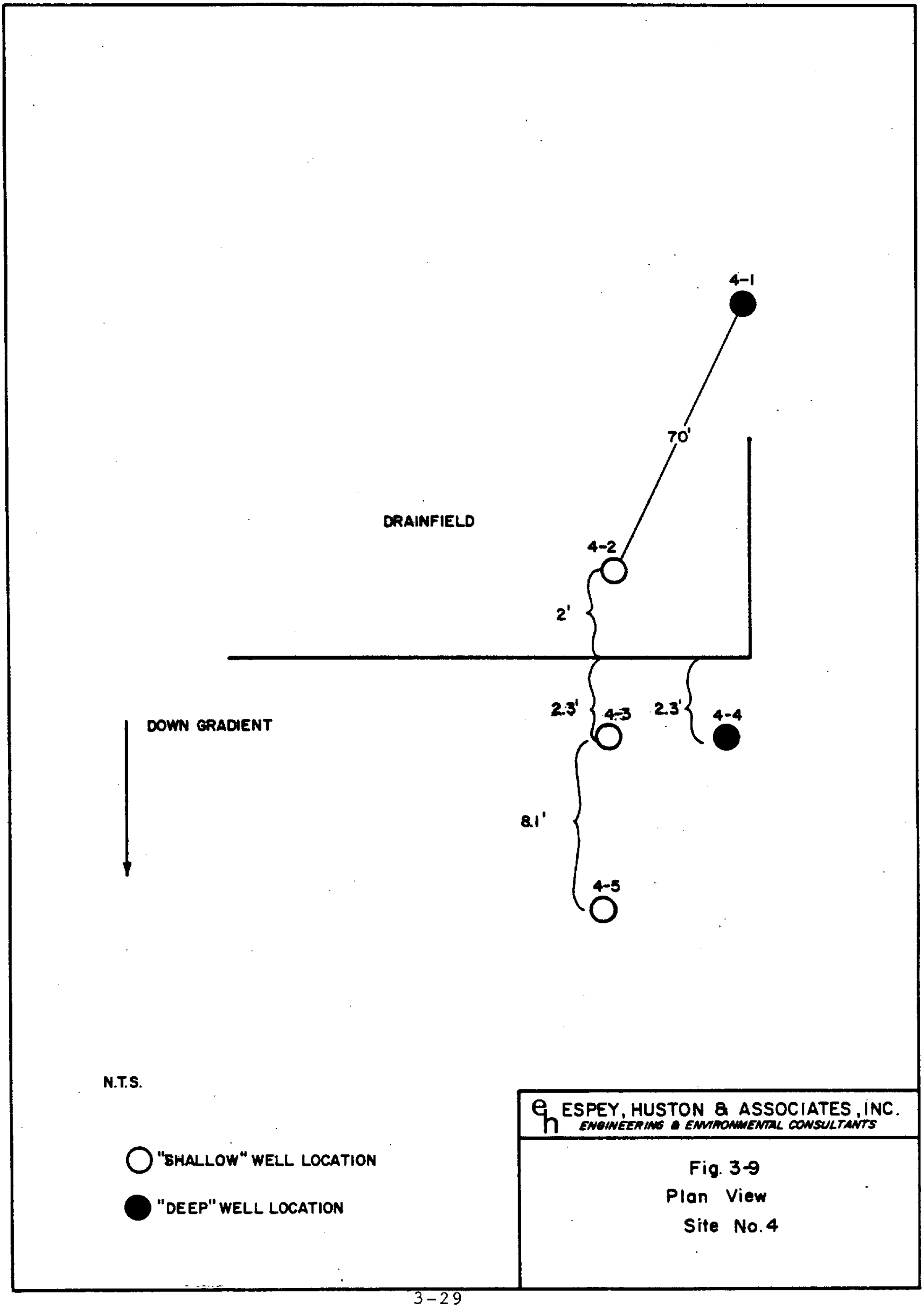

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Fig. 3-9
Plan View
Site No. 4

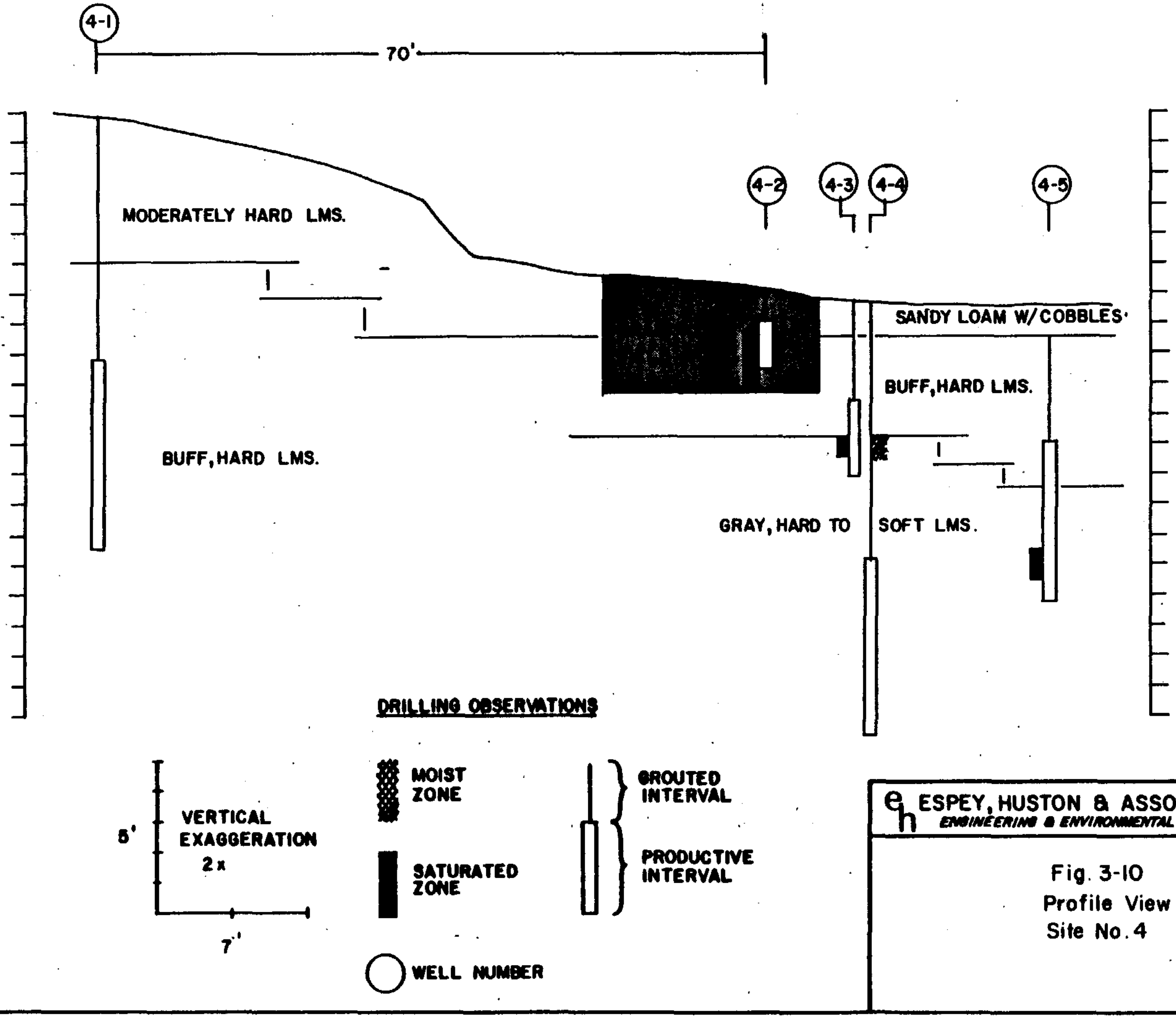

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Fig. 3-10
Profile View
Site No. 4

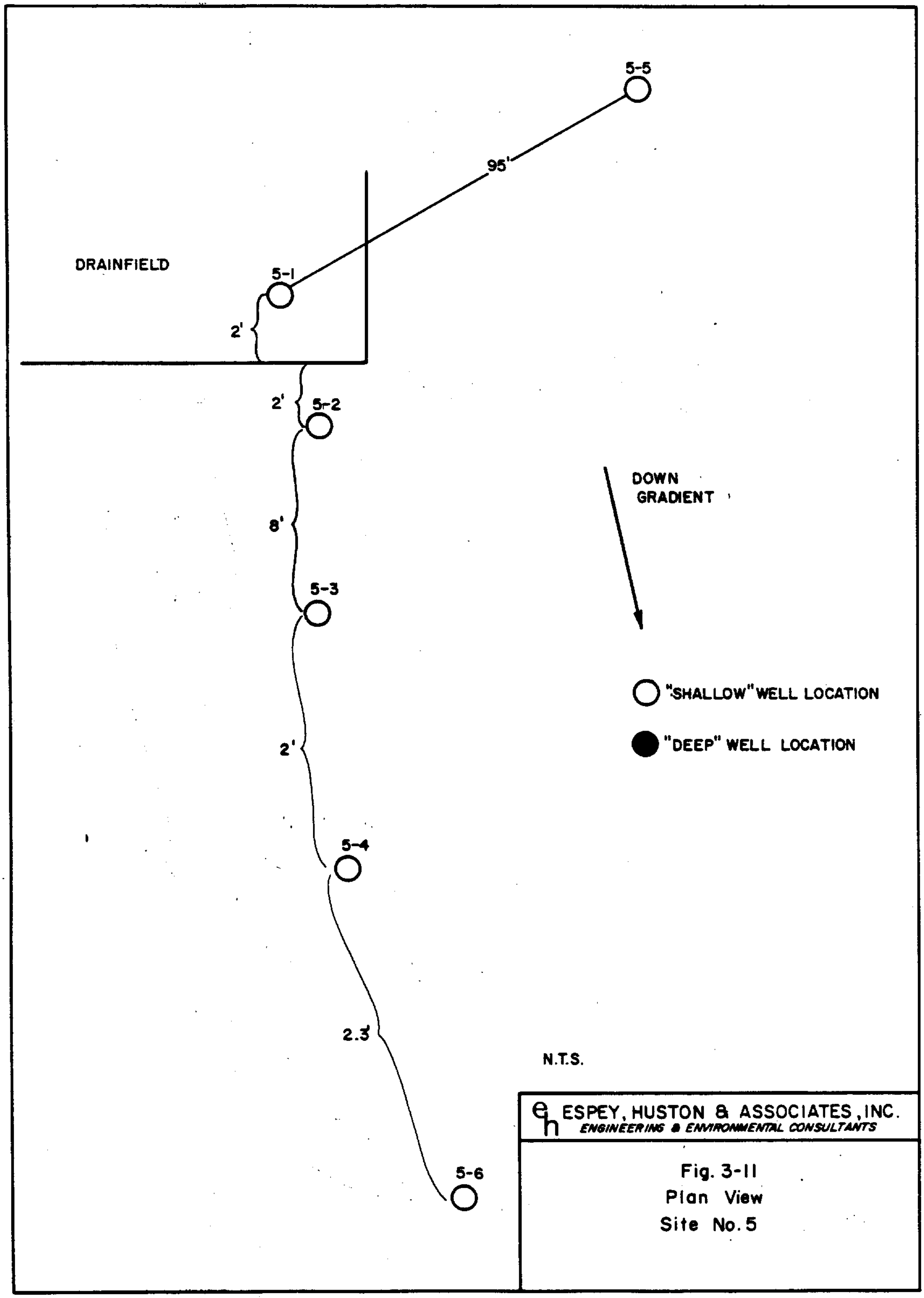

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Fig. 3-11
Plan View
Site No. 5

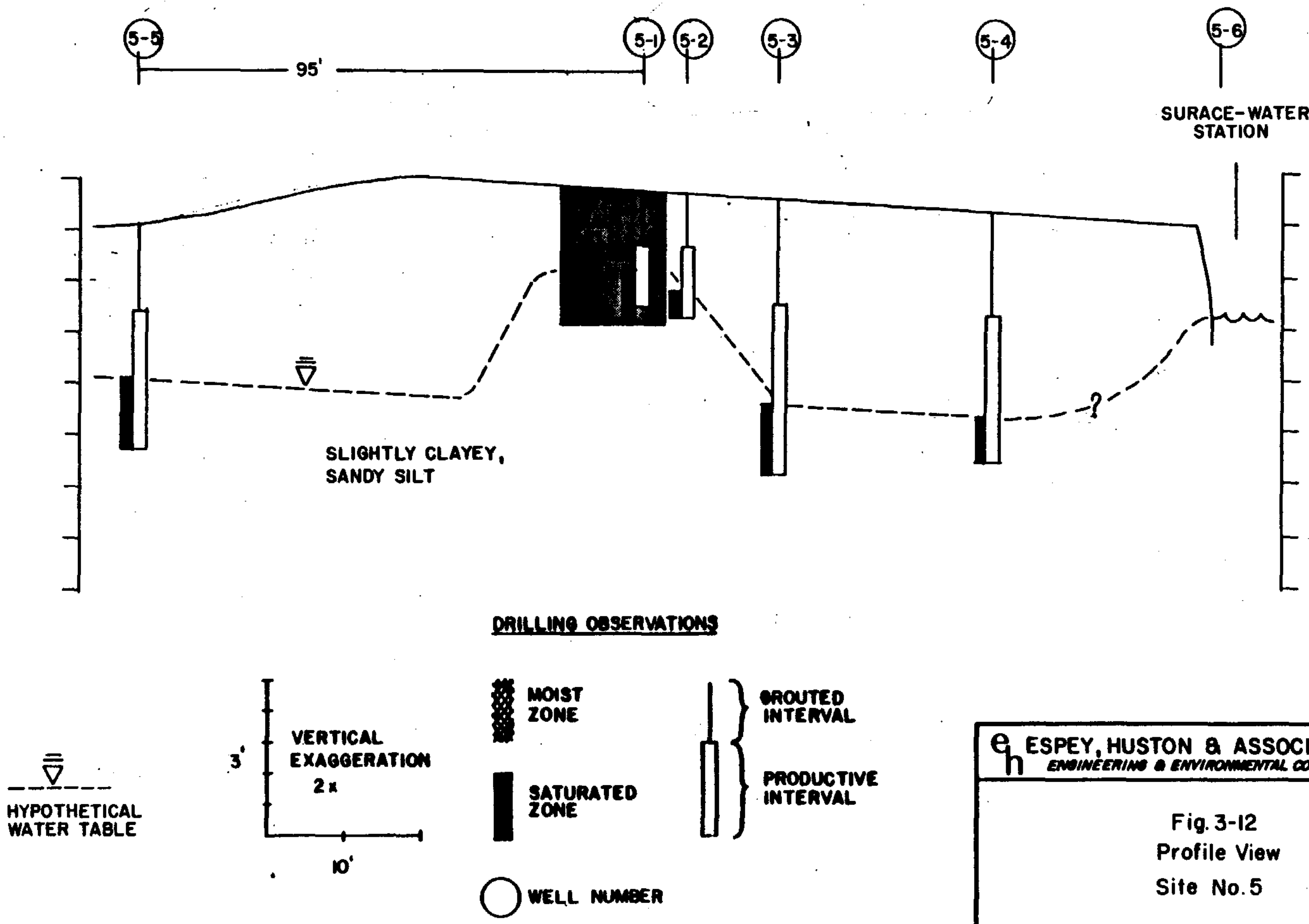

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Fig. 3-12
Profile View
Site No. 5

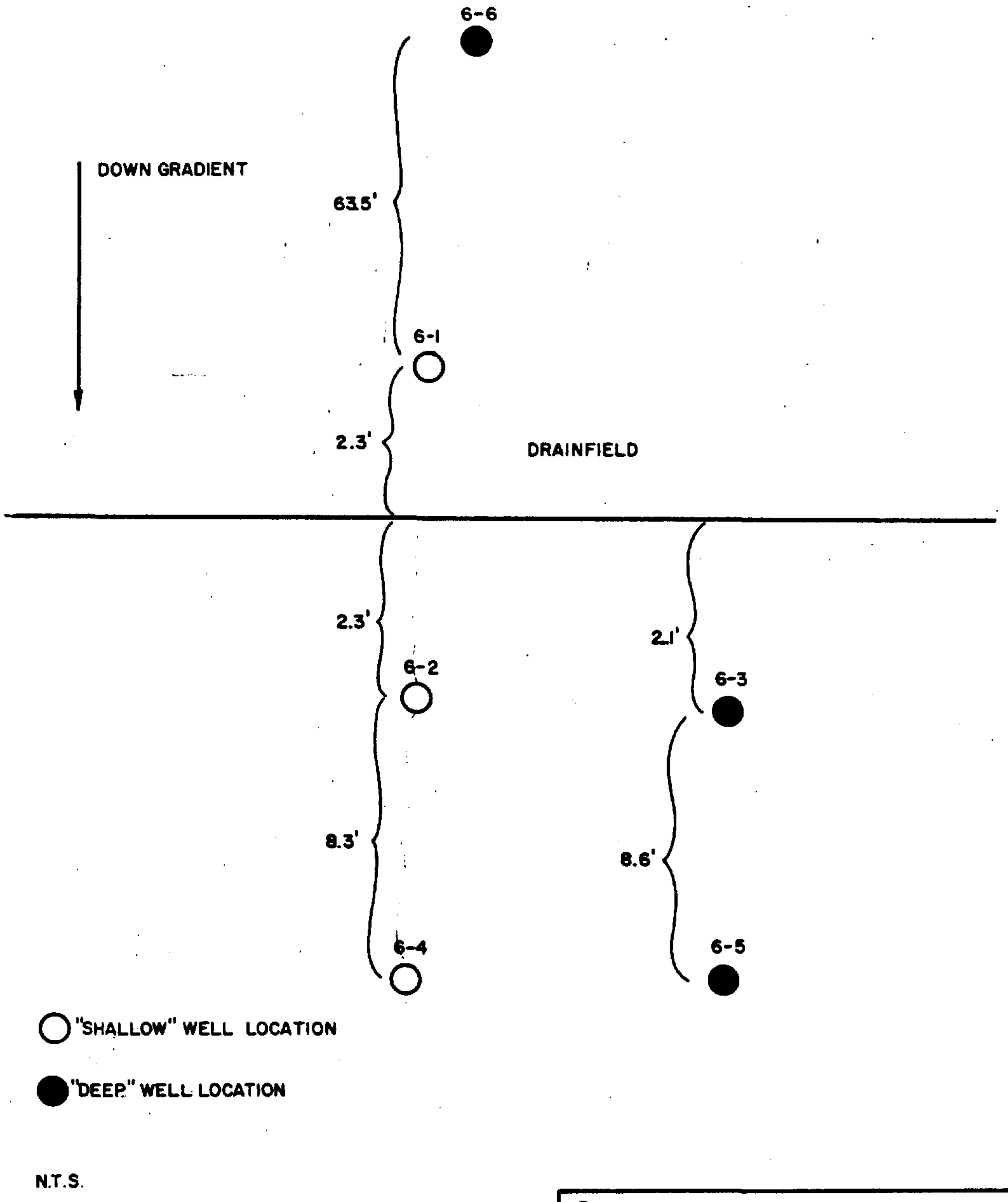

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Fig. 3-13
Plan View
Site No. 6

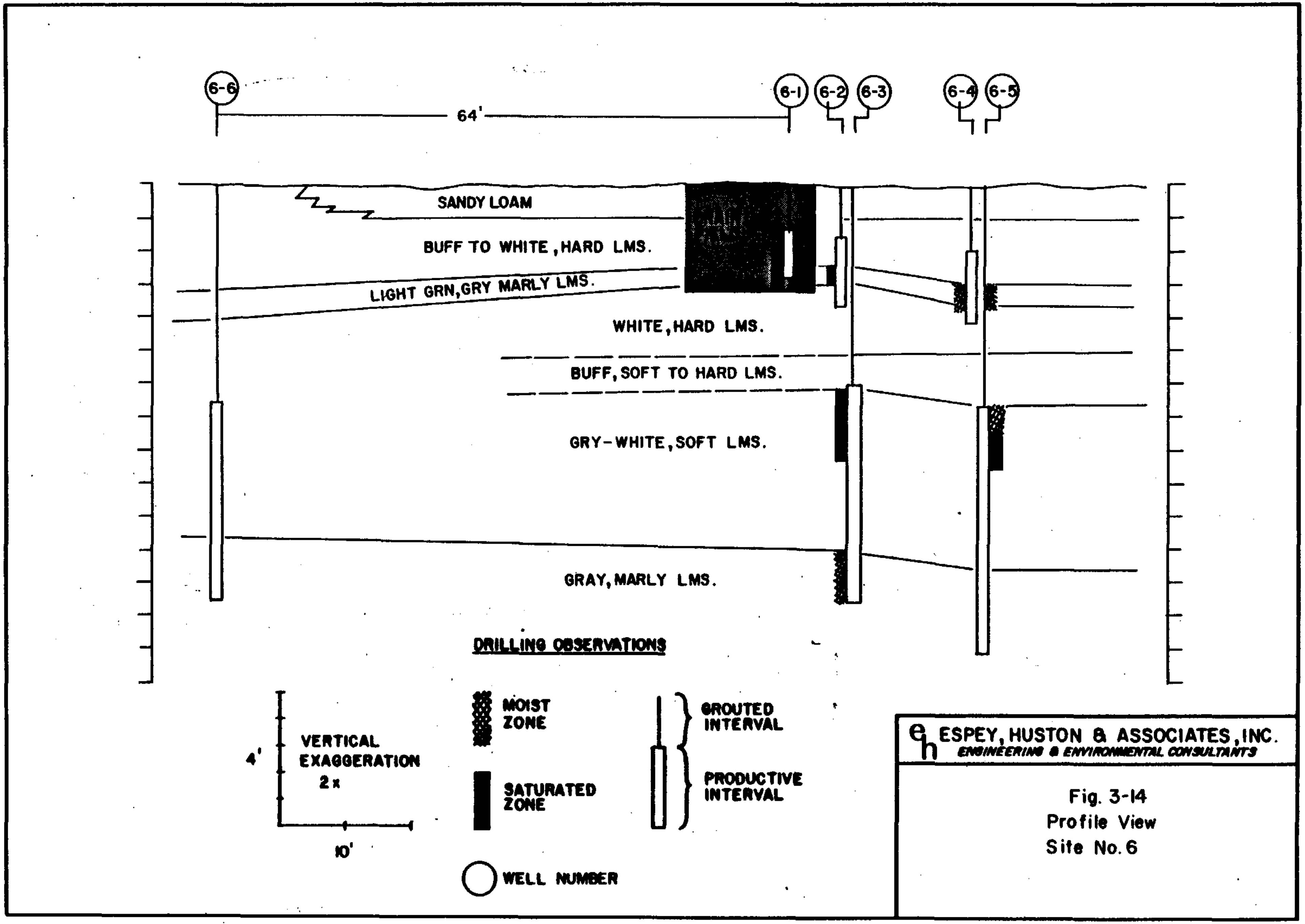

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Fig. 3-14
Profile View
Site No. 6

TABLE 3-1
MONITOR WELL COMPLETION DATA

SITE-WELL	DEPTH DRILLED (FT)	SCREENED INTERVAL (FT)	SAND PACK INTERVAL (FT)
1-1	15.25	10.25 - 15.25	9.00 - 15.25
1-2	5.00	3.00 - 5.00	2.50 - 5.00
1-3	3.50	1.50 - 3.50	1.50 - 3.50
1-4	2.35	1.15 - 2.35	1.15 - 2.35
1-5	14.60	9.60 - 14.60	8.00 - 14.60
2-1	4.65	3.15 - 4.50	2.00 - 4.65
2-2	5.25	3.25 - 5.25	2.50 - 5.25
2-3	14.00	8.95 - 13.95	7.00 - 14.00
2-4	5.15	3.15 - 5.10	3.00 - 5.15
2-5	14.10	9.10 - 14.10	8.00 - 14.10
3-1	2.50	0.90 - 2.20	0.80 - 2.50
3-2	5.25	3.25 - 5.25	3.00 - 5.25
3-3	13.85	8.85 - 13.85	8.00 - 13.85
3-4	8.90	3.90 - 8.90	3.90 - 8.90
3-5	14.00	9.00 - 14.00	8.00 - 14.00
4-1	14.25	9.15 - 14.15	8.00 - 14.25
4-2	2.60	1.35 - 2.60	1.00 - 2.60
4-3	5.75	3.75 - 5.75	3.25 - 5.75
4-4	14.25	9.20 - 14.25	8.50 - 14.25
4-5	9.70	4.70 - 9.70	4.50 - 9.70
5-1	2.15	1.15 - 2.15	1.00 - 2.15
5-2	2.25	1.25 - 2.25	1.00 - 2.25
5-3	5.35	3.40 - 5.35	2.00 - 5.35
5-4	4.85	2.75 - 4.85	2.00 - 4.85
5-5	4.35	2.40 - 4.35	1.65 - 4.35
6-1	2.75	1.50 - 2.75	1.35 - 2.75
6-2	3.65	1.90 - 3.55	1.50 - 3.65
6-3	12.50	7.40 - 12.40	6.00 - 12.50
6-4	4.15	2.15 - 4.15	2.00 - 4.15
6-5	14.10	9.10 - 14.10	6.65 - 14.10
6-6	12.50	7.50 - 12.50	6.50 - 12.50

4.0 LOADING ESTIMATES

The monitoring well data were analyzed in order to estimate constituent mass loadings from the test site septic systems. Test site loadings were then employed to obtain estimates of areal loadings from the study watersheds.

4.1 METHODOLOGY

Pollutants emanating from a septic system drainfield can be grouped into the general categories of conservative and nonconservative constituents, and distinct types of behavior can be anticipated. Conservative constituents are those which exhibit no appreciable decay or generation reaction kinetics, but instead, display concentration gradients in response to hydraulic effects, such as dilution. Conversely, constituents subject to reaction kinetics are labelled as nonconservative. In order to estimate mass loadings originating from a drainfield, some indication of the extant transport characteristics and alternation processes was required.

Based upon observed trends in the sampling data, a first-order exponential decay relationship appeared to adequately represent the constituent behavior:

$$c = c_o e^{-kx}$$

where c = constituent concentration at distance x

c_o = initial constituent concentration (in drainfield)

k = decay coefficient

The value of the decay coefficient can be estimated from the slope of the straight-line relationship. With this formulation, specific amounts of constituent attenuation, represented as the ratio of c to c_o, can be determined as a function of distance from a drainfield. The data collected in the present study are sufficient to represent only the prevailing conditions at the time of sampling. The data are not adequate for evaluation of long-term constituent adsorption effects, effects of shallow groundwater, vertical migration of constituents, or other transport phenomena.

Sampling data at each test site were plotted as concentration versus lateral distance from the drainfield on a semilogarithmic scale. Straight line fits to the data were estimated for each sampling date, and a composite fit was also drawn.

For the present analysis, the distance required for decay of 95 percent of the initial concentration was identified as the point of "complete attenuation". Selection of a 95 percent level allowed for a degree of uncertainty in the data, associated with various potential sampling and analytical concerns.

4.2 ANALYSIS OF MONITORING DATA

Monitoring well data for each test site were plotted as described in the preceding section. In general, the data exhibited anticipated trends at the majority of sites. Some data sets were severely limited due to extremely dry conditions that persisted over much of the study period. For each data set, a least squares fit was also obtained. Plots of the sampling data are presented in Appendix B. Concentration data and time of travel results at two sites using lithium as a tracer are described in Appendix C.

Phosphorus

Total phosphorus data for the test sites are displayed in Figures B-1 through B-6 in Appendix B. Considering the uncertainties inherent in a monitoring program of this nature, the data generally exhibited good conformance to a first order decay relationship, particularly for test sites 1, 2, and 4. The total phosphorus concentration is attenuated rapidly with distance from the drainfield. At Site 1 for example, the phosphorus concentration is reduced 95 percent at a distance of 10.5 feet, based upon the least squares fit displayed in Figure B-1. Attenuation distances for all sites are shown in Table 4-1.

Observed trends for orthophosphate phosphorus were similar to the total phosphorus behavior (Fig. B-7 through B-12). Reduction of the orthophosphate concentration to a 5 percent level was achieved at a distance of 8.3 feet at Site 1, for example. Phosphorus attenuation could be attributable to plant uptake and sorption on soil particles.

Nitrogen

Organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen were analyzed in the present study. Organic nitrogen concentrations were obtained by subtracting the ammonia from the kjeldahl nitrogen. Organic nitrogen displayed variable trends as shown in Figures B-13 through B-18. Several processes could account for a decrease in organic nitrogen concentration, including adsorption to soil particles and conversion to ammonia. Ammonia nitrogen concentrations generally decreased with distance from the drainfield (Figures B-19 through B-24). Decreases in ammonia could be attributed to uptake by plants, adsorption, or nitrification reactions in the soil. Data for nitrite nitrogen is relatively sparse, and consistent trends are not apparent (Figures B-25 through B-30). Nitrite is an intermediary compound in the nitrification cycle, and concentrations are usually low. Nitrate data exhibit varying trends, as shown in Figures B-31 through B-36. At Site 1 for example, nitrate concentrations generally display a gradual decay with distance. Attenuation of nitrate could be attributable to plant uptake or denitrification. Adsorption to soil particles is not considered a significant factor in nitrate dynamics. Nitrate data for other sites indicate a trend of increasing concentration, illustrated most clearly at Site 4. An increase in nitrate concentration could be indicative of nitrification of ammonia to nitrate, or could indicate a concentrating effect of evapotranspiration. At Site 5, nitrate data displayed increasing concentrations, followed by a trend of decreasing concentrations.

BOD

BOD data are displayed in Figures B-37 through B-42. In general, trends of decreasing concentration with distance are indicated for the test sites. At Site 4 for example, the BOD dropped to 5 percent of the initial concentration at a distance of 8.5 feet. BOD reduction could be attributable to bacterial action and sorption reactions.

Chloride

Chloride is traditionally considered a conservative constituent, that is, it is not subject to appreciable decay reactions. In soil systems, chloride is relatively mobile, and is often used as a hydrodynamic tracer. Chloride concentrations would be expected to remain relatively steady, or possibly display an increasing trend due to the concentrating effect of evapotranspiration. In addition, data from other studies suggest that some adsorption to soil can occur. Data for test Sites 2 and 3 are relatively sparse. At Sites 1, 4, 5, and 6, chloride data display a general increase in concentration, as shown in Figures B-43 through B-48.

Fecal Coliform

Data for fecal coliform are shown in Figures B-49 through B-54. Observed trends are generally variable. A general decrease in concentration is indicated at Sites 1, 2, and 6. At Site 3, an increase in concentration is exhibited. Bacterial dynamics in a soil system are complicated. The variability in trends could be attributed to sampling and analytical difficulties. Patterns of increasing and decreasing concentration may be indicative of growth and declining phases of the bacterial population. Interference from naturally-occurring bacteria in the soil may also be a factor contributing to the absence of definite trends. In general, it is assumed for the purposes of the present study that a trend of decreasing concentration constitutes typical behavior.

4.3 ESTIMATION OF TYPICAL LOADING RATES

4.3.1 Potential Source Loads

An objective of the present study was to estimate typical constituent loading rates originating from individual onsite septic systems, in order to estimate mass loadings to adjacent waterbodies. Monitoring results, discussed in the preceding section, indicated that constituents vary in their mobility through the soil. Transport characteristics are summarized below:

phosphorus — loads were attenuated within a short distance from the drainfield;
nitrogen — nitrate appeared to be mobile, its transport limited primarily by hydraulics;
BOD — loads were attenuated within a short distance from the drainfield;
chloride — chloride appeared to be mobile, its transport limited primarily by hydraulics;
fecal coliform — trends were highly variable; loads would be expected to be attenuated within a short distance from the drainfield.

Based upon these results, only loadings of nitrate nitrogen and chloride, which can be considered as conservative constituents, demonstrated significant mobility through the soil. However, the possibility exists that transport of other constituents could also be substantial under certain conditions, such as movement through fractured or faulted strata.

The potential source loads for septic systems were calculated, based upon the monitoring data for concentrations within the drainfields obtained in the present study. These constituent concentrations were multiplied by a typical household wastewater flow of 223 gallons per day (EH&A, 1985) in order to calculate potential source loads. (Flows for Site 6 were estimated from occupancy data.) Results are displayed in Table 4-2. These loads represent the mass potentially available for transport from the typical study drainfield into the adjacent soil, where the loads are subject to additional attenuation processes.

4.3.2 Watershed Loading Estimates

Based upon the results of this study, watershed loads were projected based upon proximity to an adjacent waterbody. As discussed in the preceding section, only nitrate and chloride loads displayed significant mobility in the soil. Other constituents were completely attenuated within short distances from the drainfields. Though the data indicated that nitrate and chloride levels in down-gradient monitoring wells exhibited no significant decay, there was no evidence that loads travelled even 50 feet from the test site drainfields. Recognizing that the test site data were limited, it was postulated that nitrate and chloride loads could potentially travel greater distances under long-term conditions. Transport of nitrate and chloride would be limited primarily by hydraulics (and plant uptake and denitrification in the case of nitrate). The maximum horizontal distance that effluent could theoretically travel through the shallow soil zone was estimated using the Thornthwaite method for calculation of evapotranspiration loss under average annual conditions (see Appendix D). With this technique, it was estimated that a horizontal transport distance of approximately 300 ft could be encountered. In reality, the potential extent of horizontal transport would be reduced by vertical migration. To be conservative, a zone circumscribing a distance of 500 feet around the study reservoirs was defined, and loadings of nitrate and chloride were calculated based upon the estimated number of septic systems located within the zone and the potential source loadings described in the preceding section. The potential source loadings were reduced by 50% to account for physical or hydraulic limitations, such as impermeable strata and vertical migration. Attenuation of nitrate loads by vegetative uptake or denitrification may also occur (see, for example, Canter and Knox, 1985).

To allow for some potential loadings due to short-circuiting through fractures or faults, calculations were performed on the basis of an assumption that five percent of the systems in the 5000-ft zone of each subwatershed could potentially contribute additional loads. A 50% attenuation of short-circuited mass loadings was assumed to account for movement through some finite depth of soil prior to, during, or subsequent to transport through a fracture or fault. These loads were calculated for each constituent based upon the potential loadings displayed in Table 4-2 and the estimated total number of septic systems located within the subwatershed. This assumption of short-circuiting was arbitrary, and was postulated to account for recognized geologic and soil limitations within the study area. The actual percentage of systems experiencing short-circuiting may be more or less than five percent. The data collected in the present study provided no evidence of such short-circuiting, and there exist no historical data to assist in the quantification of this type of loading. Subsequent estimates of watershed loadings are developed both with and without incorporation of the short-circuiting assumption.

4.3.2.1 Existing Conditions

Watershed loadings from septic systems for existing conditions were estimated as described in the preceding section. Dwelling density estimates for existing conditions in the study watersheds were employed (see Section 2.0). Estimated annual loadings of nitrate and chloride from nearshore areas are shown in Table 4-3. These are the only constituents with the potential to leach through the soil to the reservoirs, based upon the results of the present study. If short-circuiting exists, it could result in transport of a variety of constituents in addition to nitrate and chloride. Assumed loadings due to short-circuiting in the subwatersheds are displayed in Table 4-4. The estimated total loadings incorporating both the nearshore loads and short-circuited loads are presented in Table 4-5, representing the summation of loads in the two preceding tables. If the assumption of short-circuiting is not included, the nearshore loads described in Table 4-3 constitute the total loads from the watershed.

4.3.2.2 Projected Conditions

Projected developmental conditions in the study area for the year 2000 were based upon the estimates of current septic system density described in Section 2.0. For the needs of the present study, the future number of septic systems in the study area was required. The future use of septic systems will be influenced by several factors, such as the density of development on a specific tract and the availability of centralized sewer service. In addition, future onsite septic installations will include both conventional soil absorption systems and lined evapotranspiration systems. With these numerous unknowns, population projections for Travis County (TDWR, 1983) were assumed to adequately represent future septic tank-drainfield system growth. Thus, while the lakeshore areas may experience overall growth rates higher than the general county projections, it can be assumed that only a portion of this growth will use conventional septic systems, and that this portion can be approximated by the county growth rates. Projected loadings for the year 2000 are shown in Table 4-6 for nearshore areas. Short-circuiting loads are estimated in Table 4-7. Total watershed loads incorporating both nearshore and short-circuiting loads are displayed in Table 4-8.

4.4 COMPARISON TO POINT SOURCE DISCHARGE ALTERNATIVES

There are few significant point source dischargers within the watersheds of Lakes Travis and Austin, as described by Miertschin (1985). Municipal wastewater treatment plants within the watersheds are typically small, serving specific residential developments. The majority of municipal plants dispose of treated effluent via irrigation systems, often on golf courses.

Existing permit limitations for significant discharges are presented in Table 4-9. For treatment plants where phosphorus levels are regulated by permit, the allowable concentration is typically 1 or 2 mg/l as a monthly average. Total phosphorus levels for municipal discharges that do not have specific permit limitations for phosphorous were estimated at 10 mg/l.

Existing and projected point source loadings are displayed in Table 4-10. Loadings for the year 2000 were estimated using population projections developed by the TDWR (1983). Travis Vista is currently discharging at aproximately its allowable permit load. It was assumed that the load for this small development would remain at the existing level. It was assumed that the Villa on Travis plant would commence discharging and attain the allowable permit load by the year 2000.

The discharge loads tabulated in Table 4-10 are based upon current permit levels, which include BOD limitations of 10 mg/l or less. Loads were also calculated for assumed alternative permit limitations, including an ammonia nitrogen limitation of 2 mg/l and a phosphorus limitation of 1 mg/l, as shown in Table 4-11.

For comparative purposes, it was assumed that the total projected septic systems for the year 2000 were instead connected to a centralized wastewater treatment system, in order to demonstrate what the equivalent point source loads would be. Results are shown in Table 4-12, based upon estimates of 7,312 septic systems in the Lake Travis study zone and 3,217 systems in the Lake Austin study zone. Comparing the data in Table 4-12 with the septic system loadings described in Table 4-8 (combined nearshore loads and short-circuiting loads), the estimated annual loadings for BOD, total phosphorus, and ammonia nitrogen are of approximately the same order of magnitude for the two cases. Conversely, loadings of nitrate nitrogen are projected to be much higher for the centralized wastewater treatment system alternative.

TABLE 4-1

DISTANCE FOR 95 PERCENT ATTENUATION

(Feet)

Constituent	Test Sites 1	2	3	4	5	6	Notes on Attenuation
Total Phosphorus	10	13	6.5	4.7	10	30	9 ft avg residential
Orthophosphate Phosphorus	8.3	12	9.3	3.8	6.6	26	8 ft avg residential
Organic Nitrogen	238	IC	42	IC	IC	83	Inconclusive
Ammonia Nitrogen	8.0	7.9	6.3	3.2	8.8	IC	7 ft avg
Nitrite Nitrogen	51	20	8.8	IC	35	IC	Inconclusive
Nitrate Nitrogen	IC	IC	IC	IC	52	IC	Conservative
BOD	9.2	31	53	8.5	17	108	40 ft avg residential
Chloride	IC	98	46	IC	IC	IC	Conservative
Fecal Coliform	10	9.7	IC	31	120	14	43 ft avg residential

Note: IC denotes trend of increasing concentration.

TABLE 4-2

POTENTIAL SOURCE LOADINGS FROM INDIVIDUAL SEPTIC SYSTEMS

Location	Total Phosphorus	Ortho-phosphate Phosphorus	Organic Nitrogen	Ammonia Nitrogen	Nitrite Nitrogen	Nitrate Nitrogen	BOD	Chloride	Fecal Coliform
Site 1									
Avg. conc. (mg/l)	3.2	2.5	1.3	3.1	0.05	6.3	12.0	88.0	4,975
Annual load (lbs/yr)	2.2	1.7	0.9	2.1	0.03	4.3	8.2	59.7	1.53×10^{10}
Site 2									
Avg. conc. (mg/l)	5.1	4.5	0.9	36.6	0.5	2.4	24.0	36.0	24,679
Annual load (lbs/yr)	3.4	3.1	0.6	24.8	0.3	1.7	16.3	24.4	7.61×10^{10}
Site 3									
Avg. conc. (mg/l)	10.9	8.3	6.5	12.3	5.1	19.0	26.0	104.0	194
Annual load (lbs/yr)	7.4	5.6	4.4	8.4	3.5	12.9	17.7	70.6	5.98×10^{8}
Site 4									
Avg. conc. (mg/l)	2.2	1.8	1.5	4.6	0.4	0.4	17.0	86.0	14
Annual load (lbs/yr)	1.5	1.2	1.0	3.1	0.3	0.2	11.5	58.4	4.31×10^{7}
Site 5									
Avg. conc. (mg/l)	12.5	11.7	3.3	43.6	0.03	0.04	68.0	119.0	48,394
Annual load (lbs/yr)	8.5	7.9	2.3	29.6	0.02	0.03	46.2	80.8	1.49×10^{11}
Site 6									
Avg. conc. (mg/l)	0.4	0.3	1.2	1.4	0.2	0.8	12.0	378.0	661
Annual load (lbs/yr)	0.3	0.2	0.8	0.9	0.1	0.5	8.0	250.8	2.04×10^{9}
Composite									
Avg. conc. (mg/l)	6.8	5.8	2.7	20.0	1.2	5.6	29.4	86.6	15,651
Annual load (lbs/yr)	4.6	3.9	1.8	13.6	0.8	3.8	20.0	58.9	4.8×10^{10}

Note: Fecal coliform concentration in org/100 ml, load in org/yr.
Composite concentrations and loads exclude data for Site 6.

TABLE 4-3

ESTIMATED ANNUAL LOADINGS OF MOBILE CONSTITUENTS FROM SEPTIC SYSTEMS IN NEARSHORE AREAS OF THE WATERSHED

Subwatershed	Approx. No. of Septic Systems	Loadings (lbs/yr) Nitrate Nitrogen	Chloride
Hurst Creek	360	684	10,584
Hudson Bend	186	353	5,468
Cypress Creek	397	754	11,672
Pace Bend	335	636	9,849
Pedernales River	49	93	1,441
Muleshoe Bend	138	262	4,057
Sandy Creek	169	321	4,969
Arkansas Bend	551	1,047	16,199
Anderson Bend	50	95	1,470
Therman Bend	170	323	4,998
Alligator Creek	70	133	2,058
Cow Creek	86	163	2,528
Total Lake Travis	2,561	5,864	75,293
Bee Creek	121	230	3,557
Lower Lake Austin	139	264	4,087
Upper Lake Austin	21	40	617
Mid Lake Austin	21	40	617
Bear Creek	55	105	1,617
Total Lake Austin	357	679	10,495

Note: Results of the present study indicated that only nitrate and chloride exhibited significant mobility in the soil. Nearshore area was delimited as a 500-ft zone around the reservoirs.

TABLE 4-4

POTENTIAL ANNUAL LOADINGS OF ALL CONSTITUENTS DUE TO SHORT-CIRCUITING ASSUMPTION FROM SEPTIC SYSTEMS IN THE 5000-FT ZONE OF THE WATERSHED

	Loadings (lbs/yr)									
Subwatershed	Approx. No. of Septic Systems	Total Phosphorus	Ortho-phosphate Phosphorus	Organic Nitrogen	Ammonia Nitrogen	Nitrite Nitrogen	Nitrate Nitrogen	BOD	Chloride	Fecal Coliform
Hurst Creek	1,240	143	121	56	422	25	118	620	1,823	$1.5x10^{12}$
Hudson Bend	678	78	66	31	231	14	64	339	997	$.8x10^{12}$
Cypress Creek	633	73	62	28	215	13	60	316	931	$.8x10^{12}$
Pace Bend	506	58	49	23	172	10	48	253	744	$.6x10^{12}$
Pedernales River	56	6	5	3	19	1	5	28	82	$.7x10^{11}$
Muleshoe Bend	142	16	14	6	48	3	13	71	209	$1.7x10^{11}$
Sandy Creek	476	55	46	21	162	10	45	238	700	$5.7x10^{11}$
Arkansas Bend	182	21	18	8	62	4	17	264	776	$6.3x10^{11}$
Anderson Bend	217	25	21	10	74	4	21	109	319	$2.6x10^{11}$
Therman Bend	268	31	26	12	91	5	25	134	394	$3.2x10^{11}$
Alligator Creek	296	34	29	13	101	6	28	148	435	$3.6x10^{11}$
Cow Creek	86	10	8	4	29	2	8	43	126	$1.0x10^{11}$
Total Lake Travis	4,780	550	465	215	1,626	97	452	2,563	7,536	$6.2x10^{12}$
Bee Creek	557	64	54	25	189	11	53	279	819	$6.6x10^{11}$
Lower Lake Austin	905	104	88	41	308	18	86	453	1330	$1.1x10^{12}$
Upper Lake Austin	104	12	10	5	35	2	10	52	153	$1.2x10^{11}$
Mid Lake Austin	318	37	31	14	108	6	30	159	467	$3.8x10^{11}$
Bear Creek	218	25	21	10	74	4	21	109	320	$2.6x10^{11}$
Total Lake Austin	2,102	242	204	95	714	41	200	1,052	3,089	$2.5x10^{12}$

Note: This table presents potential loads based upon the assumption that 5% of the septic systems in the watershed contribute 50% of their potential loadings due to short-circuiting. Actual loads could be smaller or larger.
Coliform loads in org/yr.

TABLE 4-5

ESTIMATED ANNUAL LOADINGS OF ALL CONSTITUENTS FROM SEPTIC SYSTEMS IN THE WATERSHED INCORPORATING BOTH NEARSHORE LOADS AND SHORT-CIRCUITING LOADS

Subwatershed	Approx. No. of Septic Systems	Loadings (lbs/yr) Total Phosphorus	Ortho-phosphate Phosphorus	Organic Nitrogen	Ammonia Nitrogen	Nitrite Nitrogen	Nitrate Nitrogen	BOD	Chloride	Fecal Coliform
Hurst Creek	1,240	143	121	56	422	25	802	620	12,407	1.5x10^{12}
Hudson Bend	678	78	66	31	231	14	417	339	6,465	.8x10^{12}
Cypress Creek	633	73	62	28	215	13	814	316	12,603	.8x10^{12}
Pace Bend	506	58	49	23	172	10	684	253	10,593	.6x10^{12}
Pedernales River	56	6	5	3	19	1	98	28	1,523	.7x10^{11}
Muleshoe Bend	142	16	14	6	48	3	275	71	4,266	1.7x10^{11}
Sandy Creek	476	55	46	21	162	10	366	238	5,669	5.7x10^{11}
Arkansas Bend	182	21	18	8	62	4	1,064	264	16,975	6.3x10^{11}
Anderson Bend	217	25	21	10	74	4	116	109	1,789	2.6x10^{11}
Therman Bend	268	31	26	12	91	5	348	134	5,392	3.2x10^{11}
Alligator Creek	296	34	29	13	101	6	161	148	2,493	3.6x10^{11}
Cow Creek	86	10	8	4	29	2	171	43	2,654	1.0x10^{11}
Total Lake Travis	4,780	550	465	215	1,626	97	5,316	2,563	82,829	6.2x10^{12}
Bee Creek	557	64	54	25	189	11	283	279	4,376	6.6x10^{11}
Lower Lake Austin	905	104	88	41	308	18	350	453	5,417	1.1x10^{12}
Upper Lake Austin	104	12	10	5	35	2	50	52	770	1.2x10^{11}
Mid Lake Austin	318	37	31	14	108	6	70	159	1,084	3.8x10^{11}
Bear Creek	218	25	21	10	74	4	126	109	1,937	2.6x10^{11}
Total Lake Austin	2,102	242	204	95	714	41	879	1,052	13,584	2.5x10^{12}

Note: Watershed loads presented in this table include both the nearshore loads and short-circuiting loads, and represent the summation of loads presented in Tables 4-3 and 4-4.
Fecal coliform loads in org/yr.

Data Report
Septic Tank Loadings
To Lake Travis And Lake Austin
Contract # 55-41006

The following maps are not attached to this report. They are located in the official file and may be copied upon request.

Map 1 - Drainage Boundaries

Map 2 - Land Use

Map 3 - Disposal Suitability

Map 4- Drainage Boundaries

Please contact Research and Planning Fund Grants Management Division at (512) 463-7926 for copies.