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Nitrate and Other Nutrients Associated with Playa Storage of Feedlot Wastes

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The cattle feeding industry in the Southern Great Plains has grown rapidly since the early 70's. Presently, more than 5 million beef animals are fattened annually in feedlots within a 150-mile radius of Bushland, Texas, near the center of the Texas Panhandle (Southwestern Public Service, 1992). This is 25 percent of all cattle fattened yearly in the U.S. Many of the feedlots in the area are located around playas - shallow, dry weather lakes that have no outlet - so that runoff from the feedlots can be contained. Studies done by the USDA Agricultural Research Service (ARS), Bushland, Texas, at the time the feedlots were being established, indicated this was an environmentally sound practice because the playa clay bottoms were quite impermeable, and the underlying water table was generally more than 200 feet below the soil surface (Lehman et al., 1970; Lehman, 1972).

The leaching of feedyard runoff contaminants below a playa lake bottom was investigated by Lehman et al. (1970), who found that nitrogen compounds had not moved into the soil below 3 feet. Below 2 feet soil depth, the nitrate and nitrite concentrations were only slightly higher than for playas that had not received feedyard runoff. The feedlot playa study was repeated 5 years later by Clark (1975). Nitrate and chloride concentrations decreased drastically within the top 3.3 feet of soil. Below 3.3 feet, nitrate concentrations were lower than the public drinking water standards of 10 mg/l nitrate-nitrogen. These studies were instrumental in the use of playas being accepted by water quality officials.

Although we know of no data indicating that the practice is not satisfactory as was projected, there has been evidence in recent years that more water is leaching beneath irrigated clay soils of the area than was previously thought. Moreover, Wood (1990) has concluded that some water (1 to 2 in. $yr.^{-1}$.) may recharge from playa storage to the water table throughout much of the area overlying the Ogallala Aquifer, primarily through the playa rim, which is usually more permeable than the clay-filled playa bottom. Several of the feedlots have been using playas to retain runoff for 20 years or more, and new feedlot studies are now needed to determine if the earlier projections, based on short-term studies, were fully correct, or whether long-term waste disposal practices need to be modified to prevent contamination of ground water.

The objectives of this study were: (1) to investigate the effect of feedlot activities on the movement and redistribution of nutrients and salts in the soil and geologic profiles of playas; and (2) measure the downward movement of nitrogen (viz. nitrate and ammonium), phosphorus and total salts (as indicated by electrical conductivity) through playas. Feedlots for commercial beef, dairy and ARS research beef animals were included in the study.

Experimental Procedure

Sites

Locations of the feedlots are shown in Fig. 1. Annual lot capacities were 40,000, 300 and 200 head, respectively. The commercial lots are representative of many operations in the same soil and geologic setting, with similar climatological conditions. Continued study of the lots for many years enabled researchers to learn the impact of waste management on downslope natural playas, both through surface runoff and infiltrated water. In each case, soil cores were drilled from playa beds, rims, and upslope watershed areas (used as controls) (Figs. 2-4). Drill positions were selected to represent paths of subsurface water movement and the associated transport of chemical from the cattle feeding/holding facilities to downslope playa storage. In each case, however,

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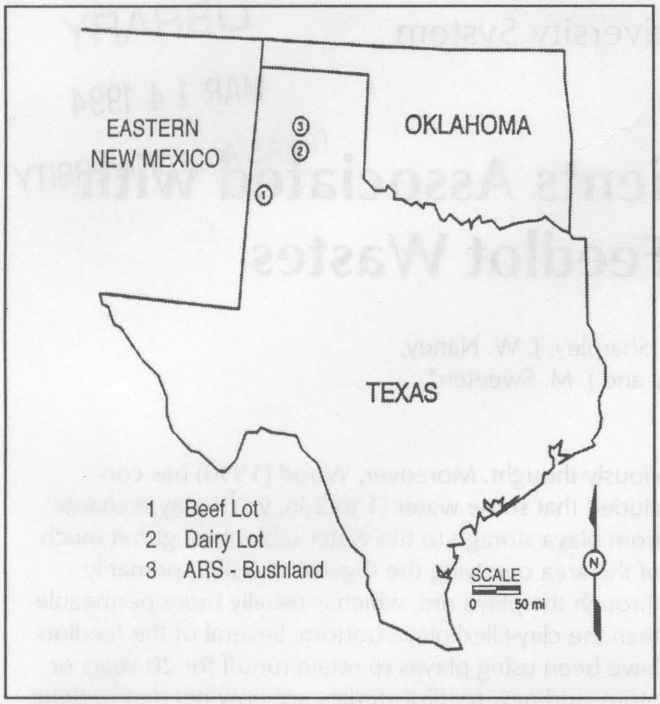


Figure 1. Key locations and study sites for the feedlot waste study.

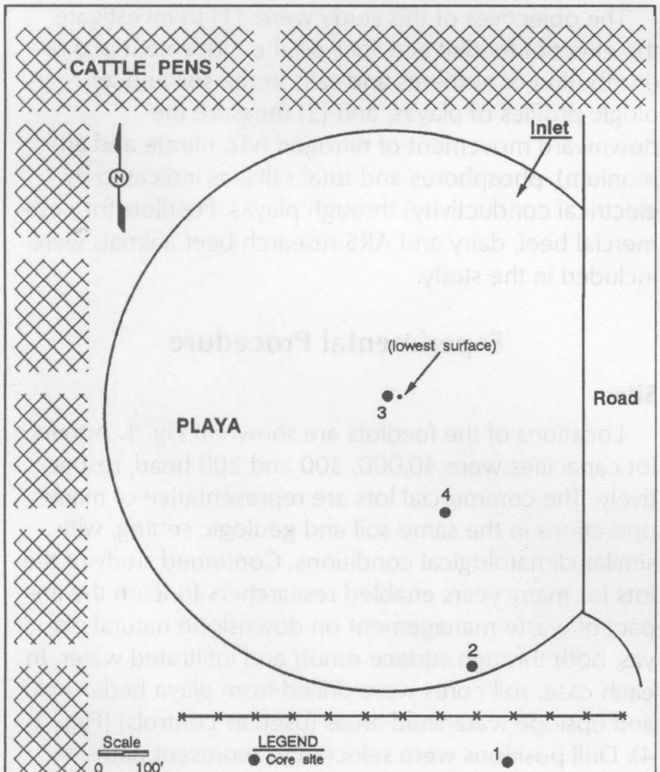


Figure 2. Layout and core sites for the beef lot.

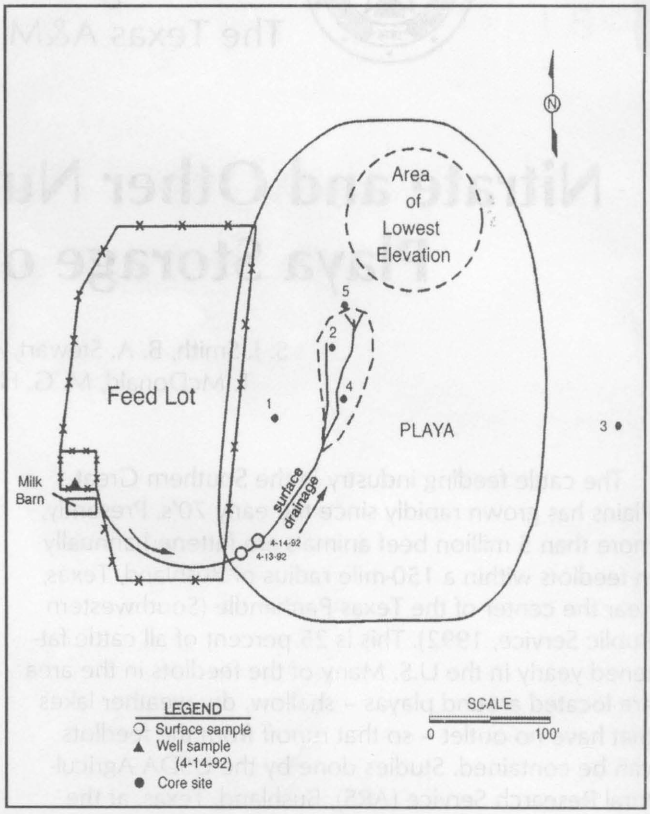


Figure 3. Layout and core sites for the dairy lot.

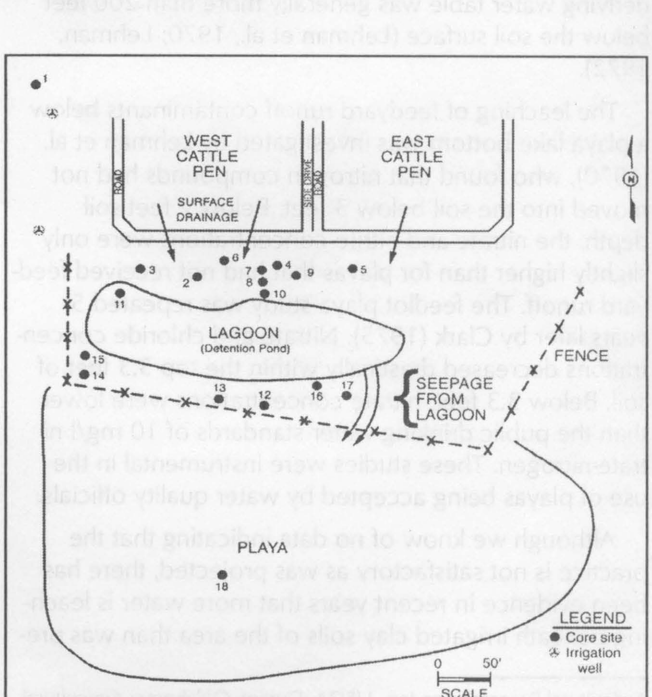


Figure 4. Layout and core sites for the ARS lot.

a prime consideration was locating positions firm enough to support the drill rig.

All three feedlots are located in an area of fine-textured soils on the Staked Plains (Llano Estacado) of the Texas Panhandle (Moore, 1958). Olton clay loam (Aridic Palleustolls, fine, mixed, thermic) dominates at the commercial beef lot, and Pullman clay loam (Torrertic Paleustolls, fine, mixed, thermic) dominates at the dairy and ARS lots. Both soils are deep and nearly level, occurring on smooth uplands. Randall clay (Udic Pelleusterts, fine, montmorillonitic, thermic) comprises the playa soil at all locations. In the playa proper, this clay may extend deeper than 14 feet. However, Randall clay typically thins upslope from the playa bottom to less than 1 foot at the rim between the playa bed and the upslope soil area. According to the Musgrave (1955) ratings, Randall clay is in the lowest hydrologic group D (<0.05 in. hr.$^{-1}$ infiltration rate), whereas the other two soils are in the next higher group C (0.05 to 0.15 in. hr.$^{-1}$ infiltration rate). Water tables at the locations are typical of the southern Ogallala region, and occur at depths of 210 to 240 feet below land surface (A.D. Schneider, ARS-Bushland, personal communication.)

Sampling Techniques

Cores at the commercial beef lot were obtained by a private well drilling firm using a heavy-duty drill rig (6-inch diameter cores) with percussion capacity to penetrate dense rock layers. With this tandem-axle, truck-mounted rig, it was possible to core all holes to a uniform 50-foot depth. Core samples at the dairy and ARS lots were obtained using a 3/4-ton truck-mounted, hydraulic press sampler (1.75-inch diameter cores) without core barrel rotation (Fig. 5a), and a Hollow Stem Auger (HSA) rig (2-inch diameter cores) mounted on a 21/2-ton truck chassis (Fig. 5b). The HSA rig provided greater accuracy, penetrated unconsolidated sediments to deeper depths, and caused minimal disturbance to the formation section being cored. With both rigs, coring was continued until an impenetrable layer was reached, generally between 10 and 20 feet.

The cores were sectioned into 6- to 12-inch segments on site, sealed in plastic bags and maintained at 4 degrees C until laboratory analysis. Holes developed by coring were plugged with a concrete-bentonite slurry to prevent surface water contamination of the subsurface. In all cases, federal/state research personnel conducted or supervised the coring and sampling process. Field work was begun in November, 1990, proceeded intermittently, and was terminated in April, 1992.

Laboratory Analysis

Upon arrival at the ARS-Durant laboratory, samples were divided for chemical and physical analysis. Samples for chemical analysis were air-dried, crushed with the aid of a porcelain mortar and pestle to pass a 60-mesh screen, mixed thoroughly and stored in sealed containers. Samples for physical analysis were maintained in a field-moist state.

Inorganic N forms (nitrate and exchangeable ammonium) involved KCl extraction using procedures described by Keeney and Nelson (1982). Total N and P were determined by a semi-micro Kjeldahl procedure (Bremner and Mulvaney, 1982), and bioavailable P was determined using iron oxide-impregnated paper strips (Sharpley, 1991). Conductivity and pH were deter-

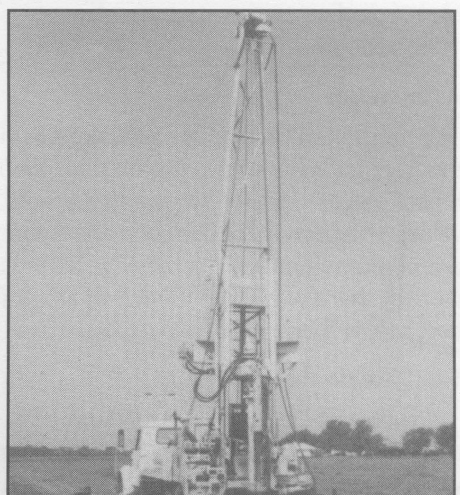


Figure 5. Drill rigs used at dairy and ARS lots. Left: Pick-up truck-mounted sampler. Right: Hollow stem auger sampler.

mined using a wheatstone bridge (Richards, 1954) and glass electrode, respectively. Soil water content was determined by drying samples for 48 hours at 110 degrees C, and particle size by the hydrometer method (Day, 1965).

Results and Discussion

This section deals mainly with overall trends and findings. Detailed analytical information for each location is available to interested persons. Data are presented on a foot basis for the first 5 feet of depth, and on a 5-foot basis thereafter. Where there were multiple borings, values were averaged. Complete data sets were not available for all playas and cores, but the results are considered adequate to address the downward movement of nutrients.

Nitrate

Nitrate profiles are indicated in Fig. 6. Maximum nitrate concentrations observed were about 65 ppm N at all three lots. At the beef lot, this value occurred 1 foot below the playa bed. By the 5-foot depth, however, values less than 5 ppm N were observed at this and other locations in the playa, indicating there was no movement of nitrate below the subsoil. At the dairy lot, some movement of nitrate through the subsoil and below the 15-foot depth was indicated at the playa rim. At other core locations, by the 10-foot depth nitrate concentrations were less than 5 ppm N. At the ARS lot, incoming waste above the lagoon raised nitrate concentrations to more than 10 ppm N down to 30 feet; otherwise, nitrate concentrations tended to be less than 5 ppm N. Therefore, at no playa was there evidence that appreciable nitrate had penetrated the playa proper below the 10-foot depth.

Ammonium

Ammonium profiles are indicated in Fig. 7. Only at the beef lot were values higher than 5 ppm N, with the higher values confined to the top 5 feet. The highest value, 385 ppm N, occurred in the 2-foot layer, with the ammonium contents decreasing sharply thereafter. Obviously, there was no evidence of ammonium penetration below the subsoil.

Total Kjeldahl N

Profiles of TKN, which represent primarily organic nitrogen, are indicated in Fig. 8. Highest values observed were in the order of 3,000 to 4,000 ppm TKN, representing a three- to four-fold increase. However, these accumulations were observed only at the beef and dairy lots, and then just in the top foot where the incoming waste was being deposited. Otherwise, the TKN contents were similar to soil receiving no waste.

Total P

Profiles of TP, which represent both organic and inorganic phosphorus, are indicated in Fig. 9. Interpretations are hampered somewhat by incomplete data and the fact that native TP may occur in erratic quantities down the profile. Nevertheless, TP accumulations to 2,000 ppm were found in the top foot of the beef and dairy lots, where the incoming waste was being deposited. Values for the ARS lot were more uniform down the profile, although some higher TP contents were observed in the waste receiving areas. Even so, there was no general indication of a TP front moving below the subsoil.

Bioavailable P

Bioavailable P values for the feedlot soil cores are given in Fig. 10. Bioavailable soil P represents P available for plant (Sharpley, 1991) and algal uptake (Sharpley, 1993), and is associated with forms stimulating eutrophication of surface waters. Bioavailable P values in the upper 5 feet of soil in the playas were generally higher than those outside the playa (Fig. 10). No movement of bioavailable P was apparent below 5 feet, with values inside and outside the three playas similar.

Conductivity/pH

Conductivity and pH values for the feedlot soil cores are given in Figures 11 and 12, respectively. The highest conductivity values observed were approximately 2,000 µmhos/cm in the surface soil (0- to 2-feet depths) at the beef and ARS lots. Below 5 feet, all values were generally less than 500 µmhos/cm, indicating little or no salt leaching. At the beef lot these values were similar to those outside the playa, but at the dairy lot playa values were somewhat higher than outside the playa. Insufficient data below 5 feet were available to make interpretations regarding the ARS lot. In the case of pH, values were similar at all lots and depths (e.g., pH 7.5 to 8.0), indicating little influence of feedlot waste storage on soil profile pH.

Soil Texture

Results of the soil texture analyses are given for the dairy and ARS lots in Figs. 13-15. Values represent sand, silt and clay down the profiles. In general, clay contents tended to be more than 40 percent and were 55 to 70 percent at the playas' centers or beds. Relatively high sand contents, 30 to 55 percent, at the playas' rims indicate a more permeable zone, and probably explain the high nitrate penetration observed for those particular sites (Fig. 6). Obviously, this permeable zone is one to avoid in the movement or storing of animal waste.

Soil Water

Soil water content profiles for the dairy and ARS lots are given in Fig. 16. Values were obtained at the time of coring. On an air-dry soil basis, they typically range from 10 to 20 percent. Soil water content was fairly uniform down the profiles, with no exceptionally dry (nonpermeable) or wet (perched water table) zones indicated.

Well/Surface Waters

Samples of well and surface waters were available for analysis at the dairy and ARS lots. These values are summarized in Table 1. The well waters were generally within potable limits, with the dairy having the highest nitrate (2.2 ppm N) and ammonium (0.8 ppm N) levels. Associated inflow and surface waste waters tended to be low in nitrate (less than 0.2 ppm N), higher in ammonium (3 to 92 ppm N) and very high in soluble phosphorus (9,000 to 69,000 ppb). Conductivities also were high (1,700 to 2,500 µmhos/cm), but pH values (7.6-7.9) were similar to those of the associated soils.

General Discussion

Results from this study involving beef and dairy operations generally support earlier views (e.g., Lehman et al., 1970; Lehman, 1972) that the "Randall Clay" playas can be used for feedlot waste runoff/storage without posing a significant contamination threat to the underlying groundwater. However, caution needs to be observed around the coarser-textured playa rim, because this area is a more permeable zone where deeper leaching of soluble chemicals may occur.

Most accumulations of chemicals occurred in the top foot of the playa soil surface. Nitrate was the chemical that leached most. Its maximum concentrations in the top 5 feet of soil were, on average, about 65 ppm N. At no location was there evidence that appreciable nitrate had penetrated the playa bottom proper below 10 feet.

It should be emphasized that our study only involved three locations - one commercial beef lot, one commercial dairy lot and the ARS lot. Also, 50 feet was the deepest depth drilled. Consequently, for more definitive conclusions, additional lots and deeper depths should be examined, particularly in the more permeable playa rim zone. Finally, simply storing feedlot runoff and waste up-slope, or in playas as currently practiced, is not a permanent solution. Efforts to utilize waste as an agricultural and/or commercial product should continue.

Table 1. Chemical properties of well and surface water at feedlots.

Site	Location	Date sampled	NO_3-N ppm	NH_4-N ppm	TKN ppm	WS-P ppb	TKP ppb	Cond. umhos/cm	pH
						well waters			
Dairy Lot	W. of playa	4-14-92	2.2	0.8	0.21	12.1	186	666	8.3
ARS Lot	N. of playa	7-4-91	1.8	0.0	0.0	4.2	20	588	7.8
	W. of playa	7-4-91	1.3	0.0	0.0	2.6	37	61	7.9
						In flow/surface waters			
Dairy Lot	S.W. of playa	4-13-92	0.0	87.6	244	69,128	99,074	2,446	7.6
	S.W. of playa	4-14-92	0.2	9.16	337	42,072	85,338	2,554	7.8
ARS Lot	N. of playa	6-19-91	0.0	2.7	15.9	9,257	12,582	1,691	7.9

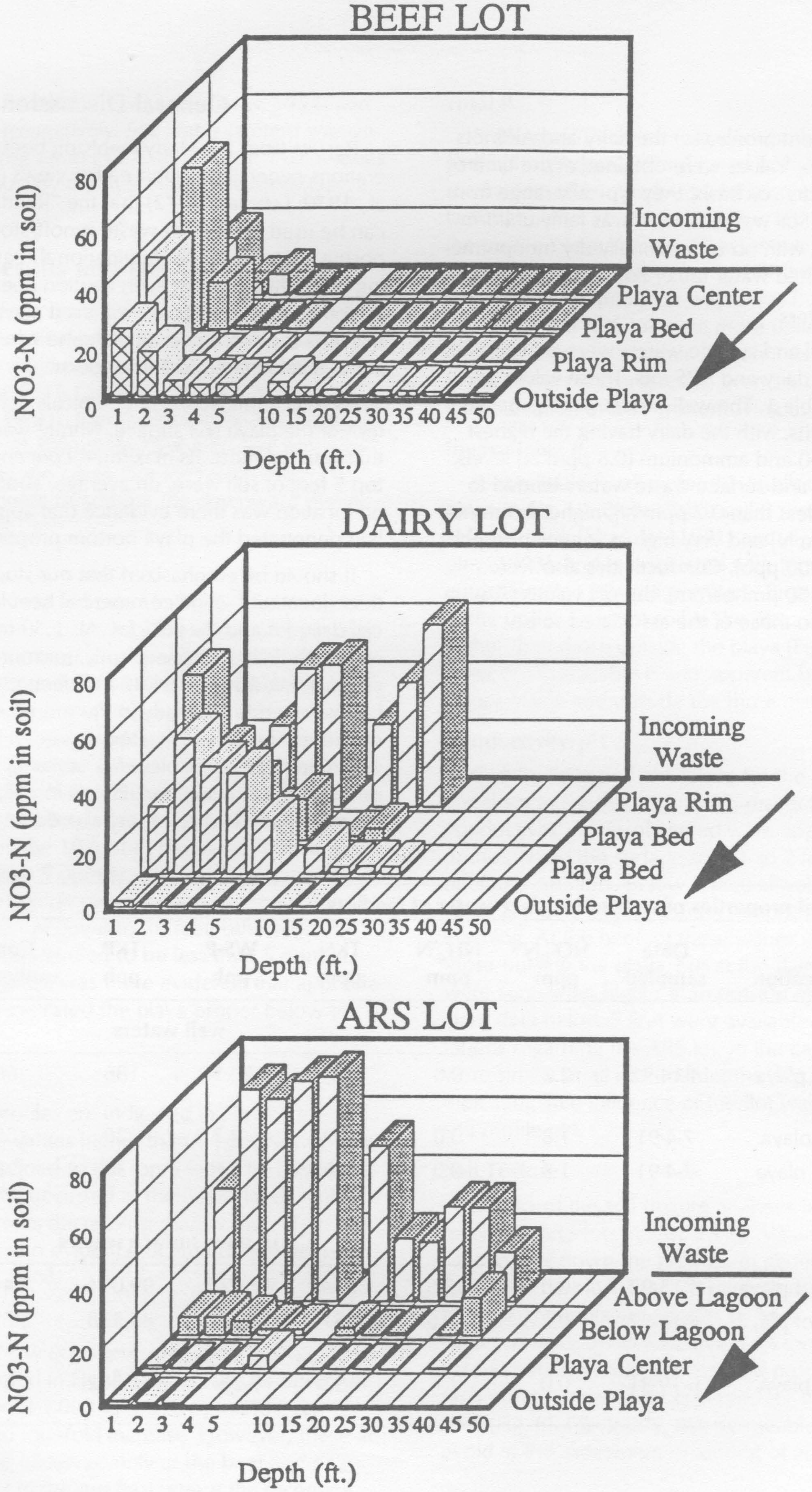
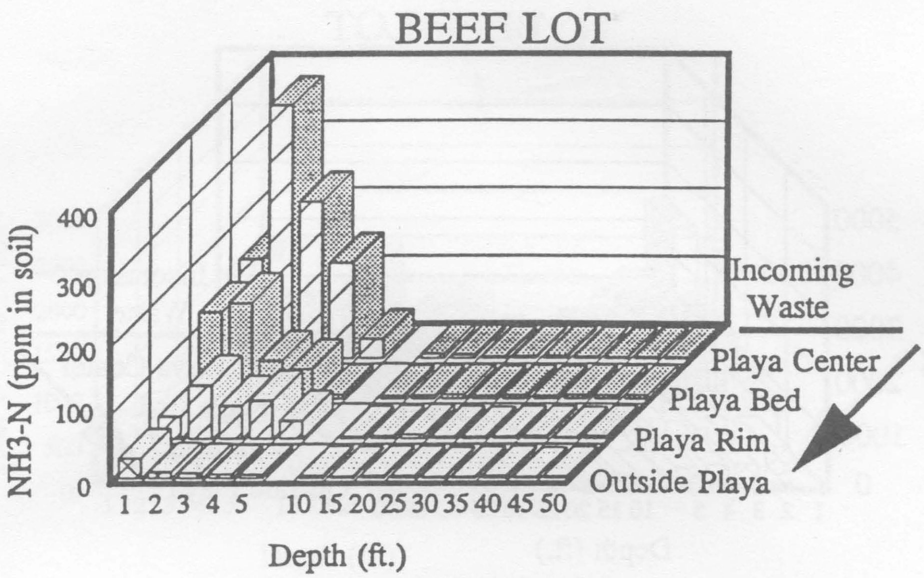
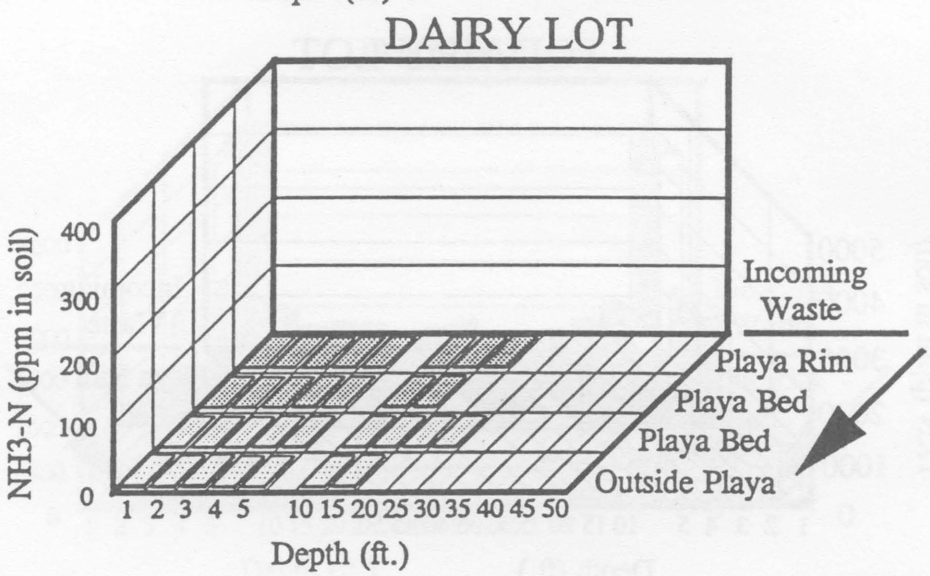


Figure 6. Nitrate-N concentrations in soil profiles at drill sites.





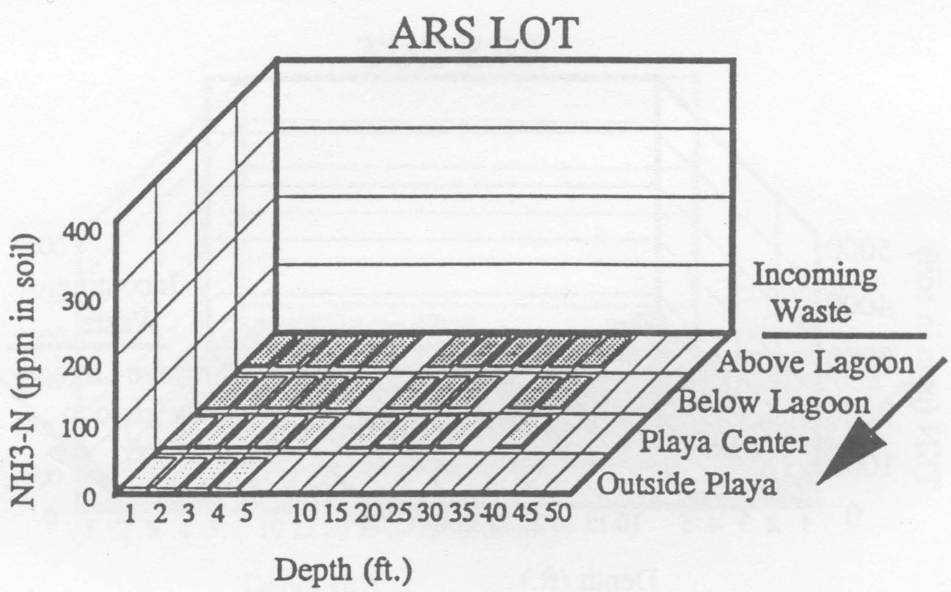


Figure 7. Ammonium-N concentrations in soil profiles at drill sites.

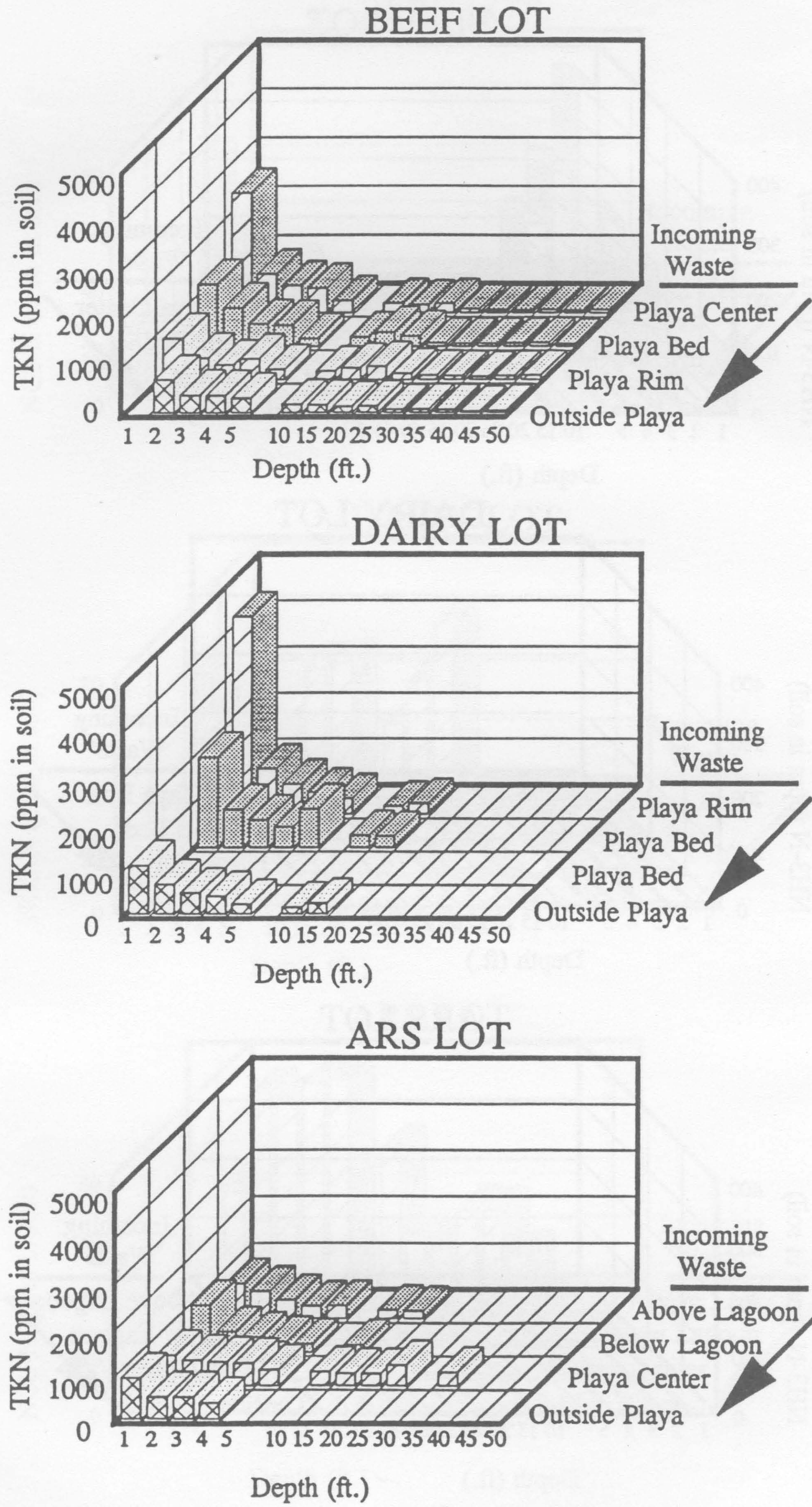


Figure 8. TKN concentration in soil profiles at drill sites.

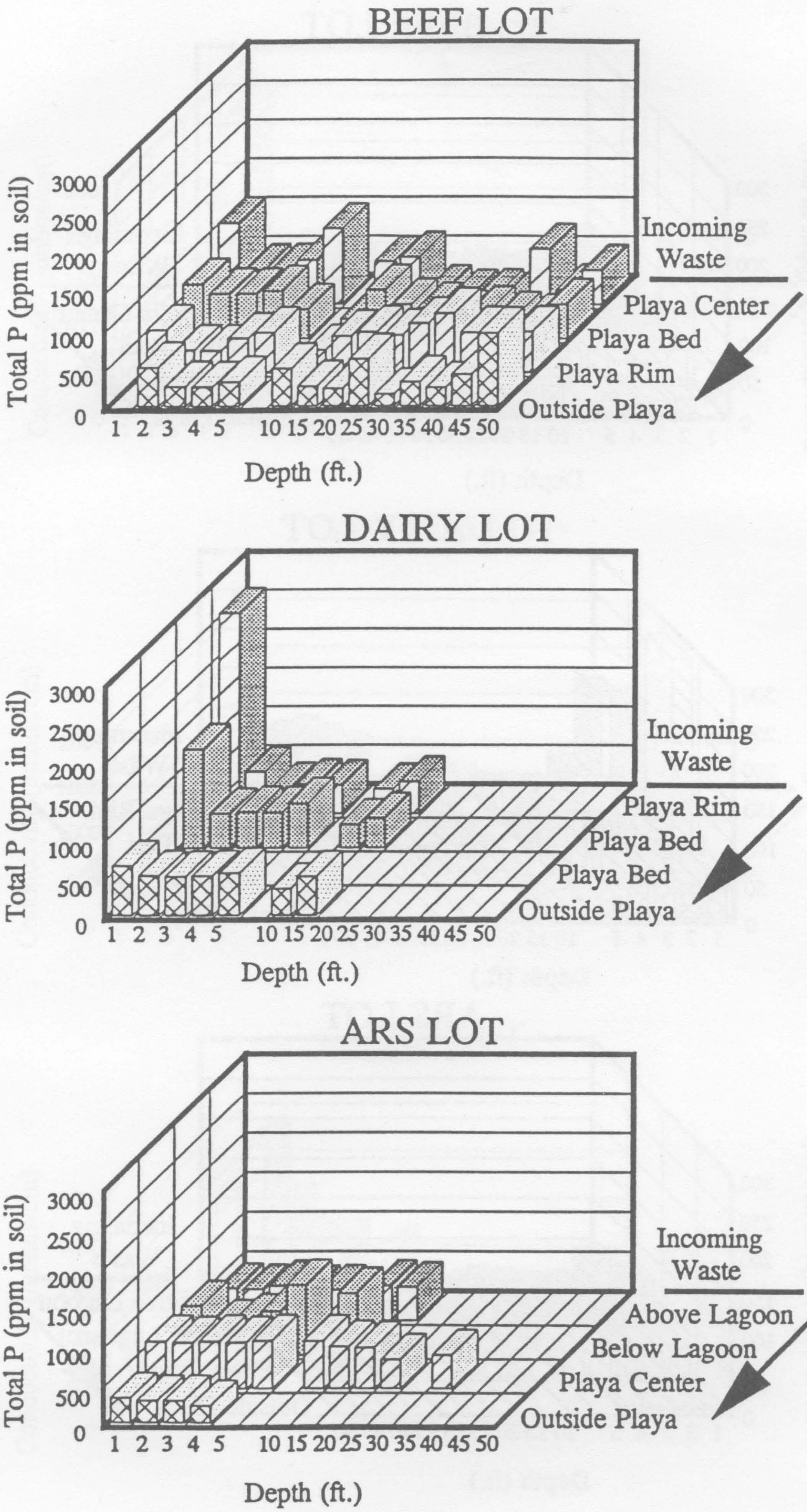


Figure 9. Total P concentrations in soil profiles at drill sites.

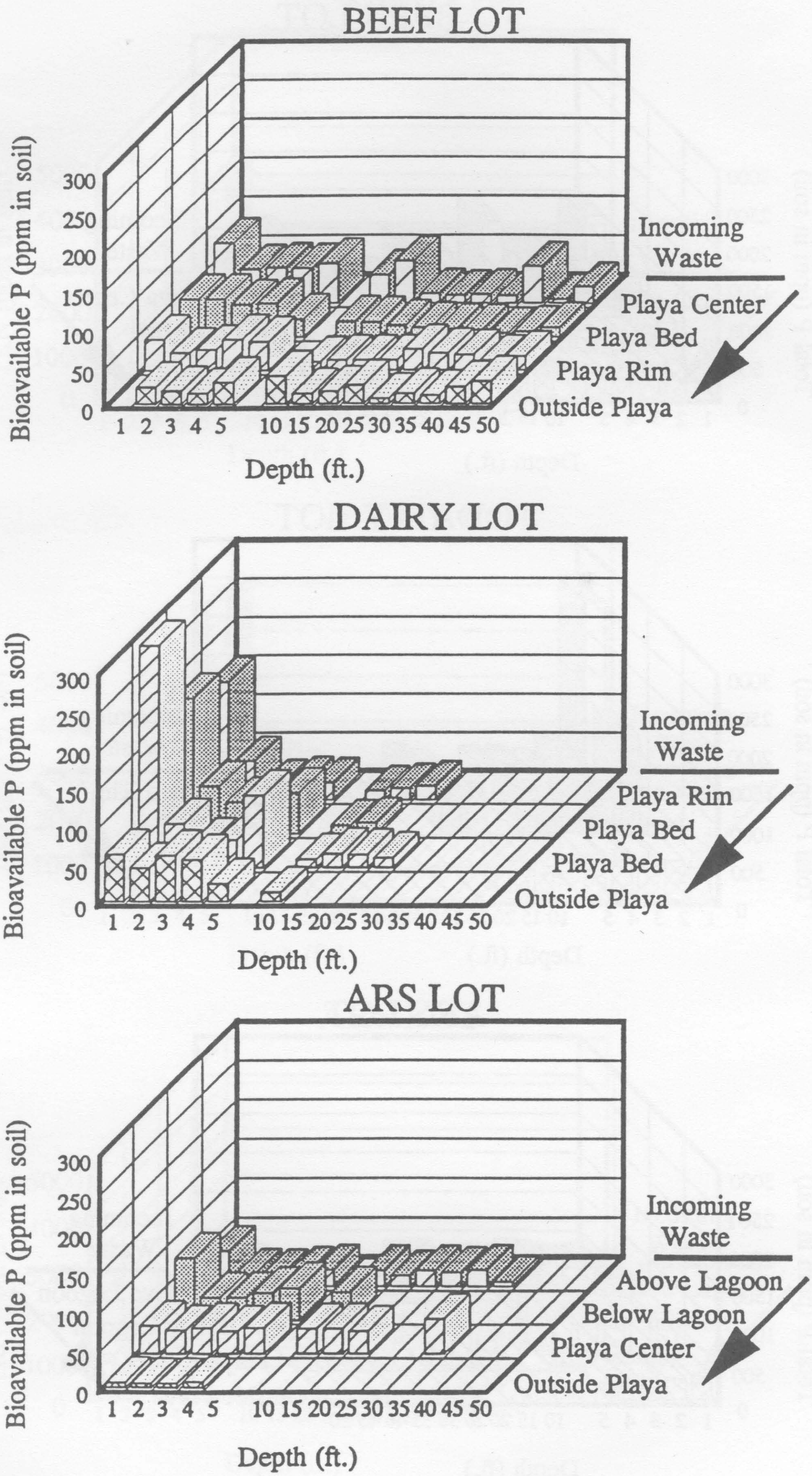


Figure 10. Bioavailable P concentrations in soil profiles at drill sites.

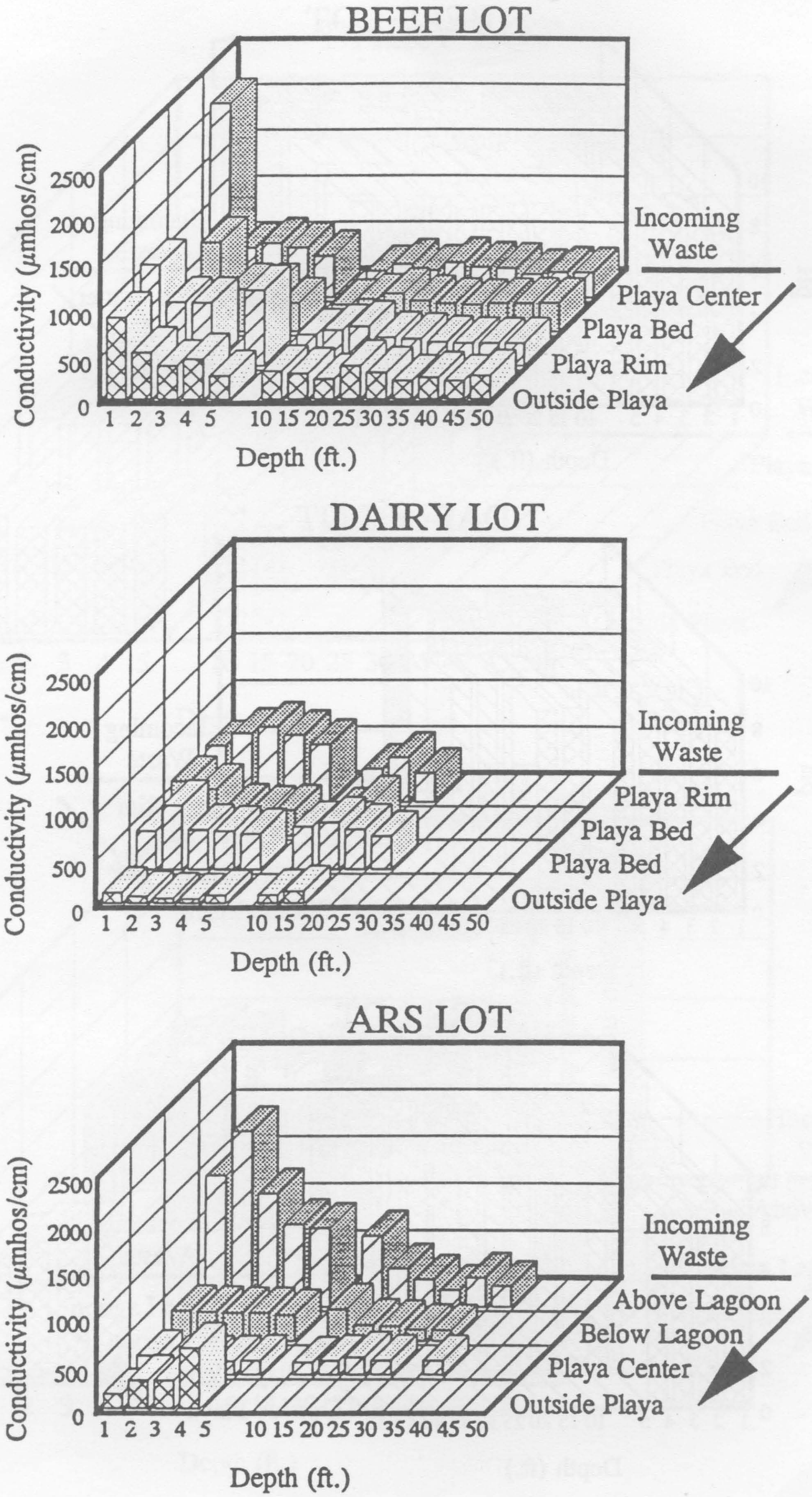


Figure 11. Conductivity values of soil profiles at drill sites.

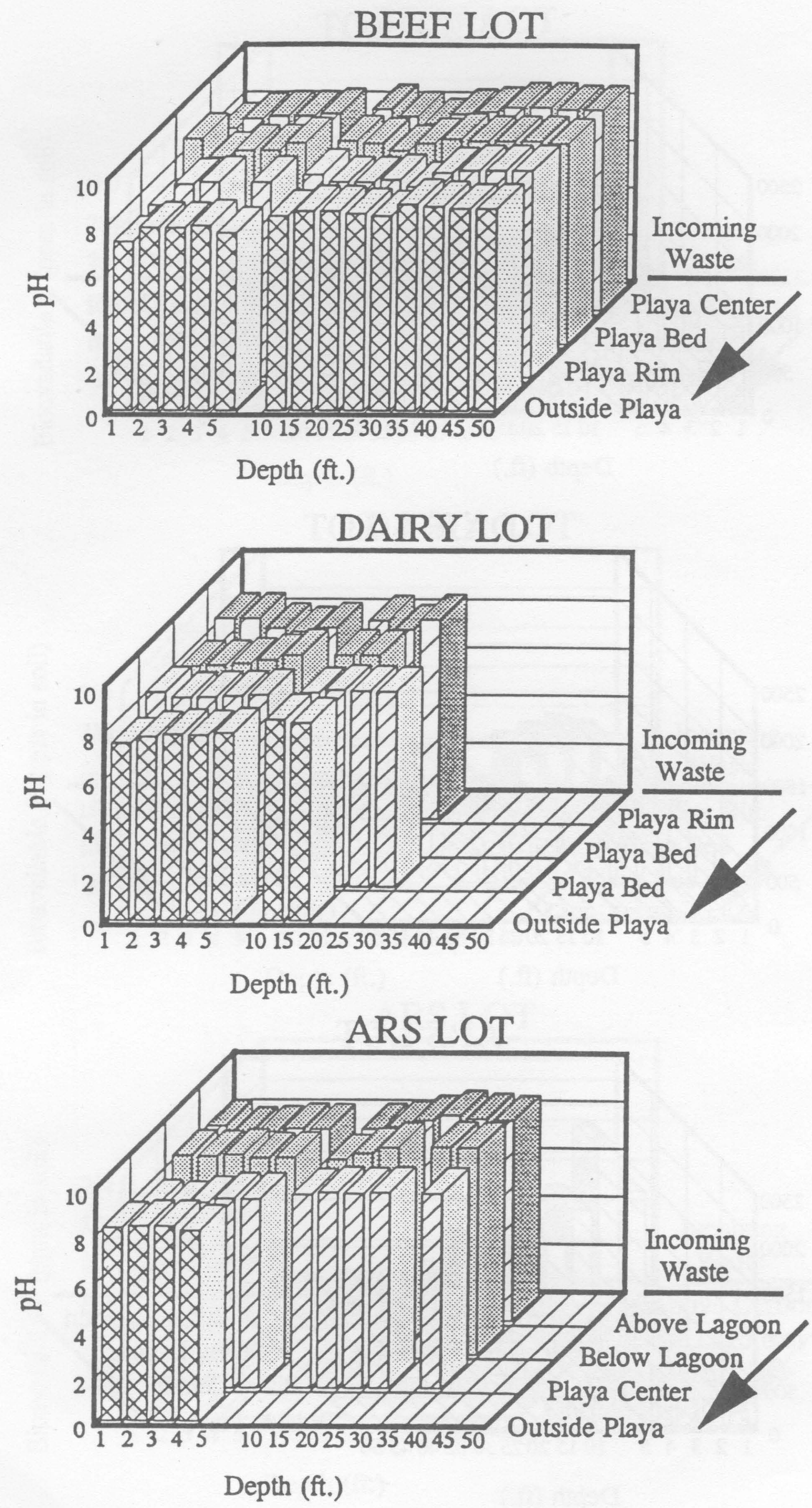
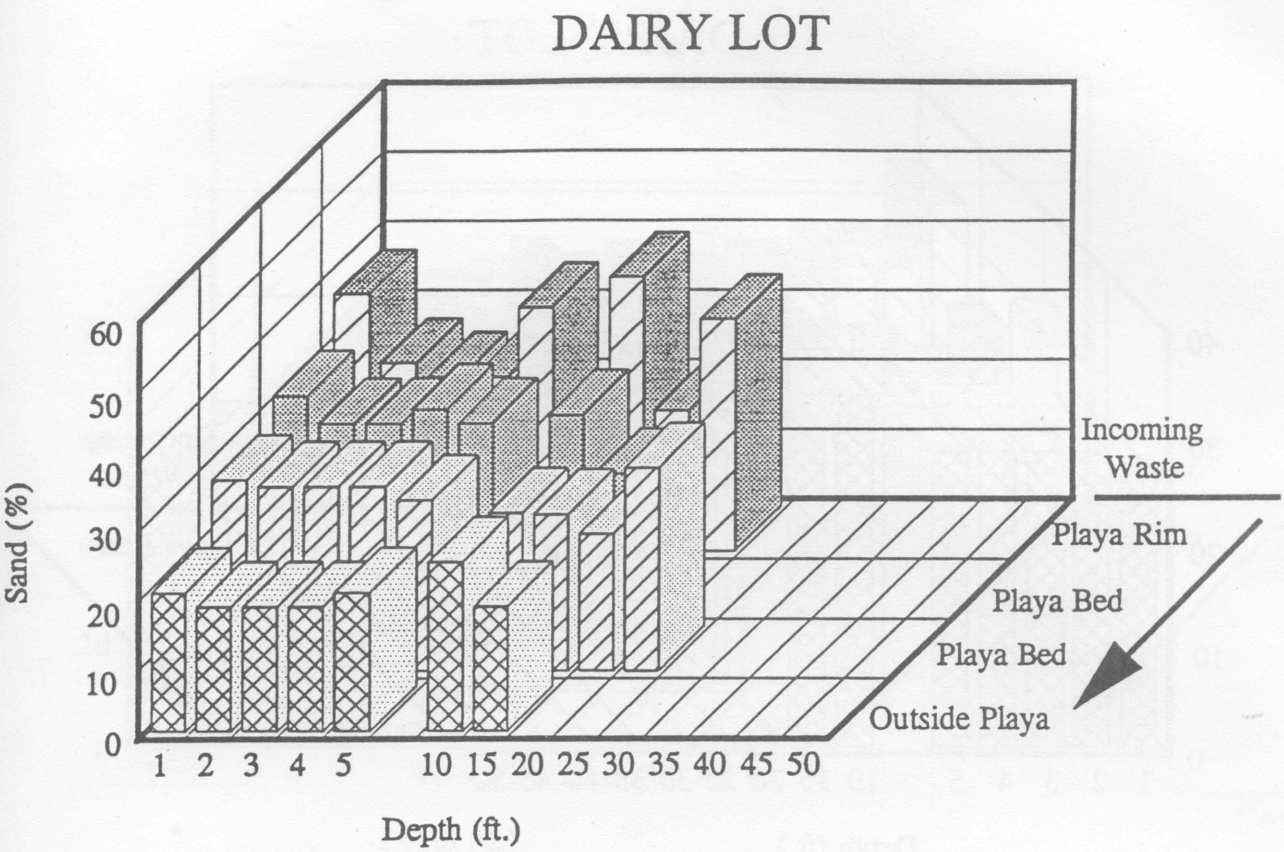


Figure 12. Values of pH in soil profiles at drill sites.



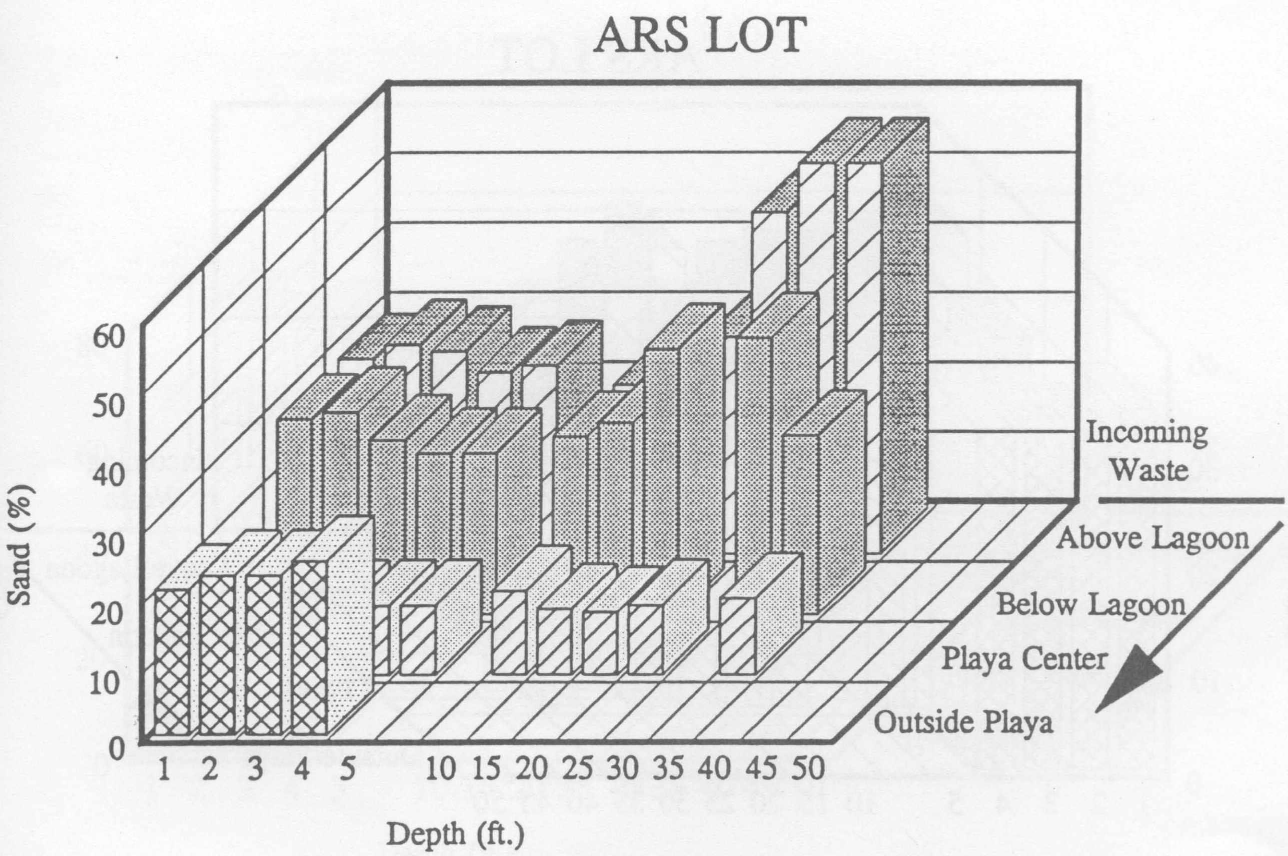
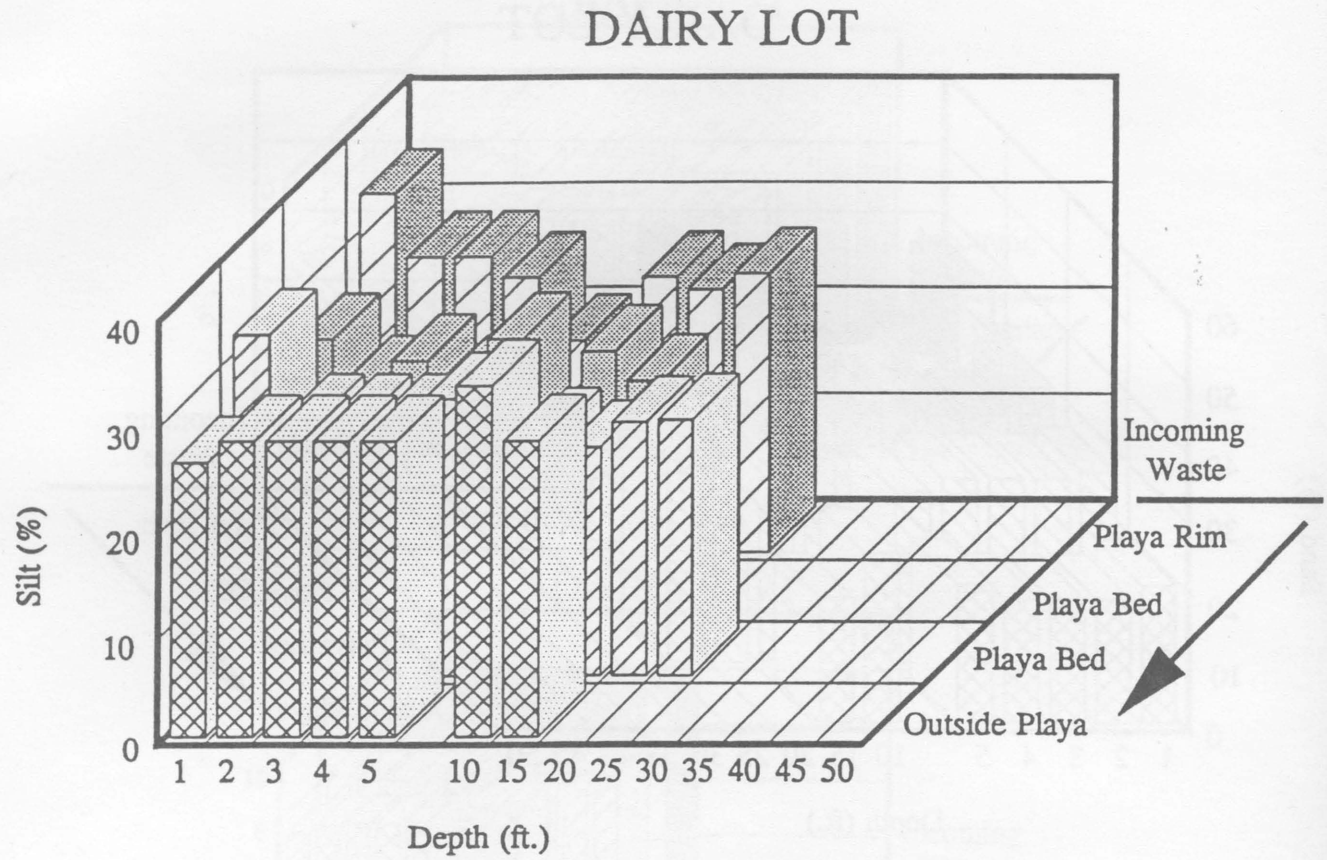


Figure 13. Sand concentrations in soil profiles at drill sites.



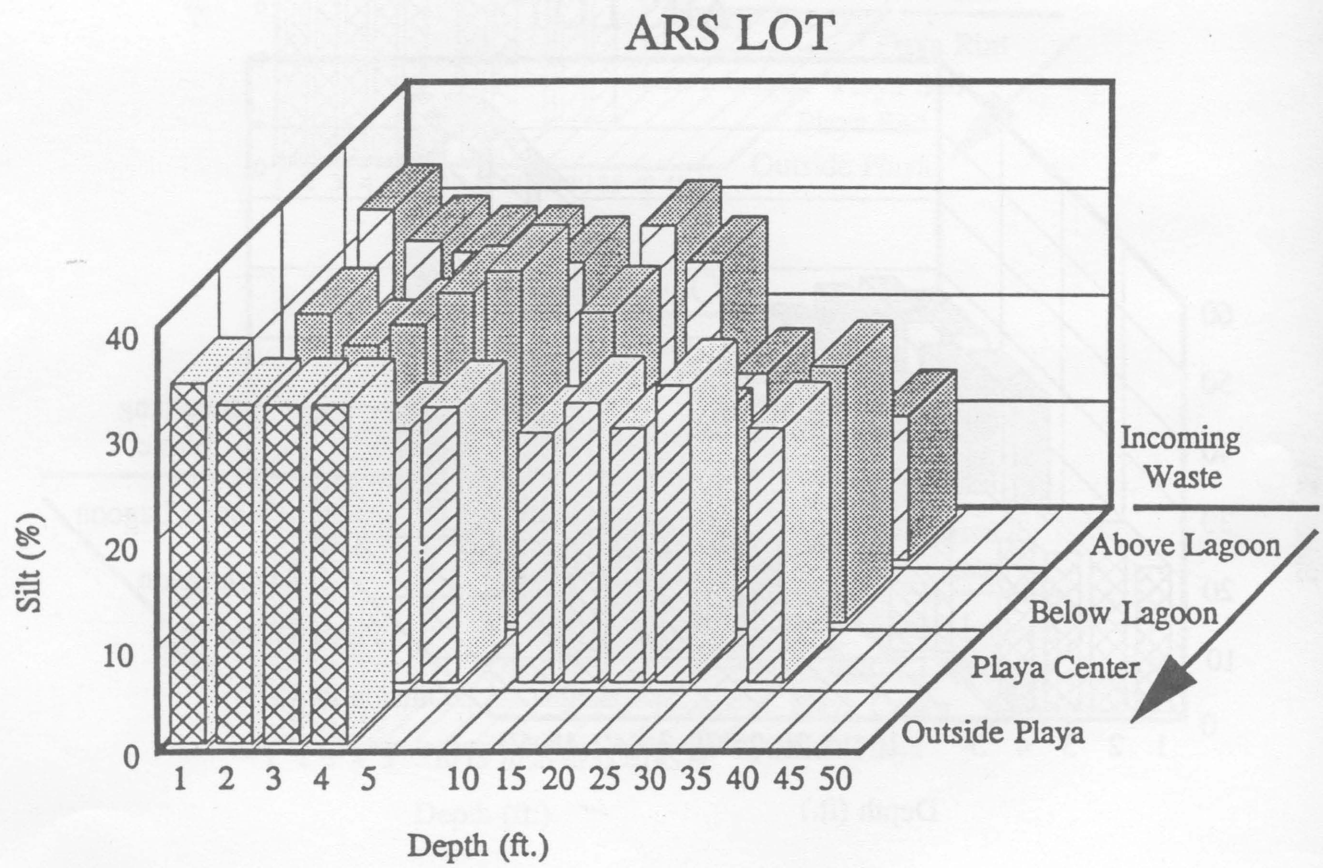
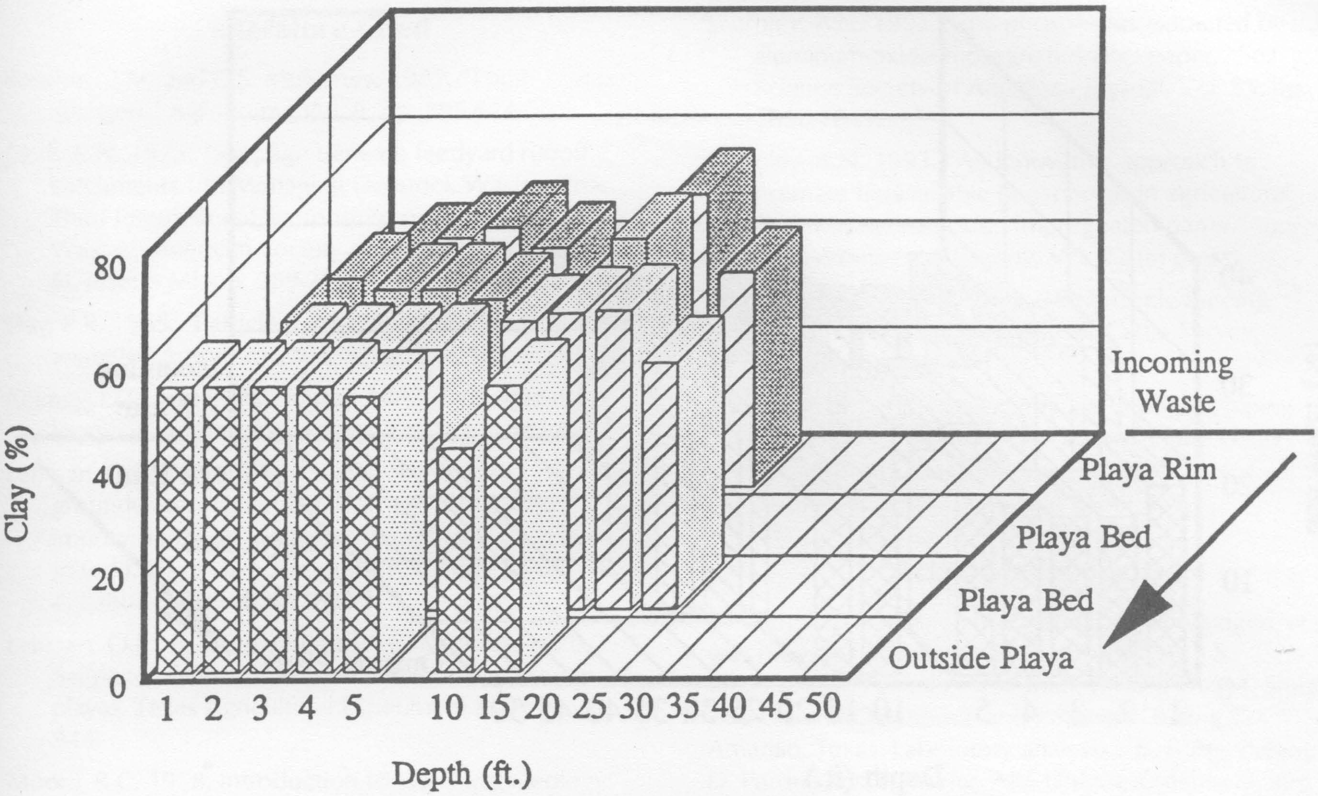


Figure 14. Silt concentrations in soil profiles at drill sites.

DAIRY LOT



ARS LOT

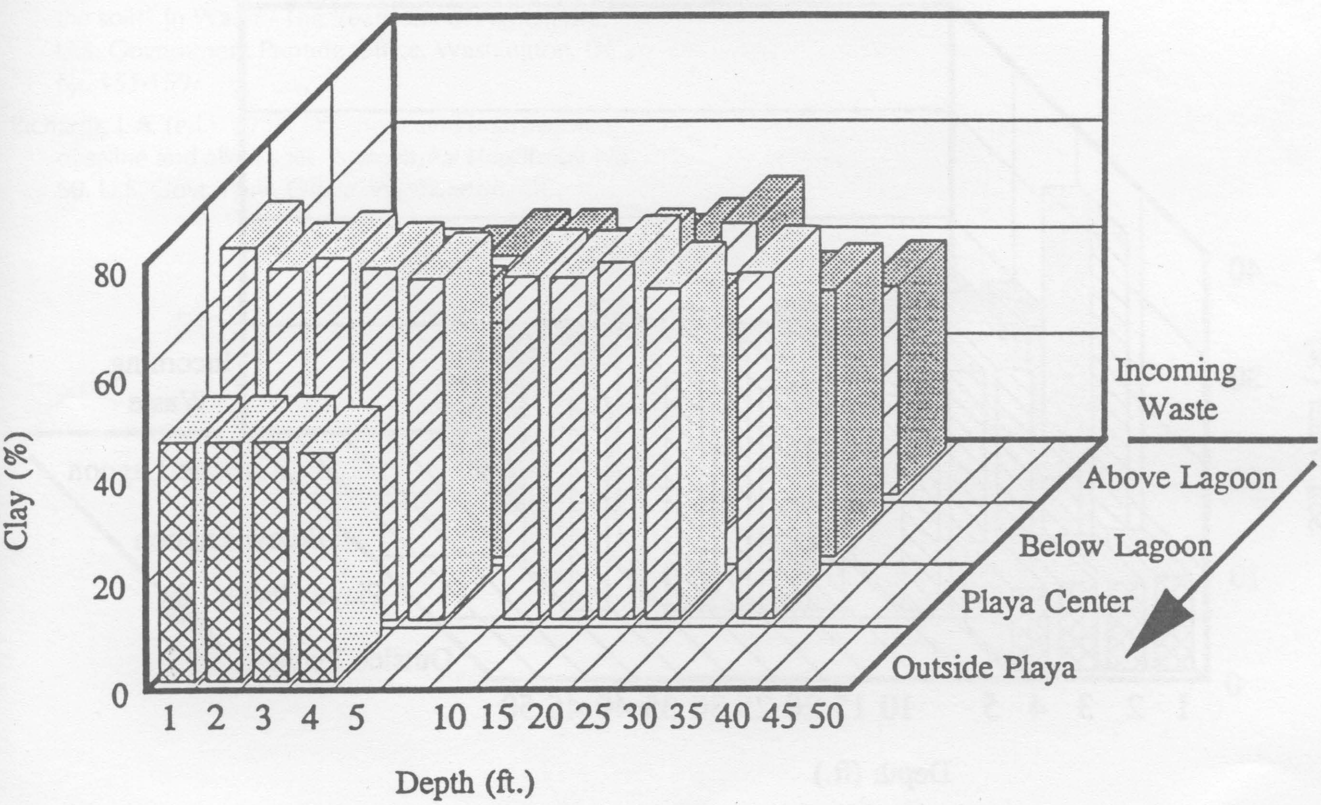
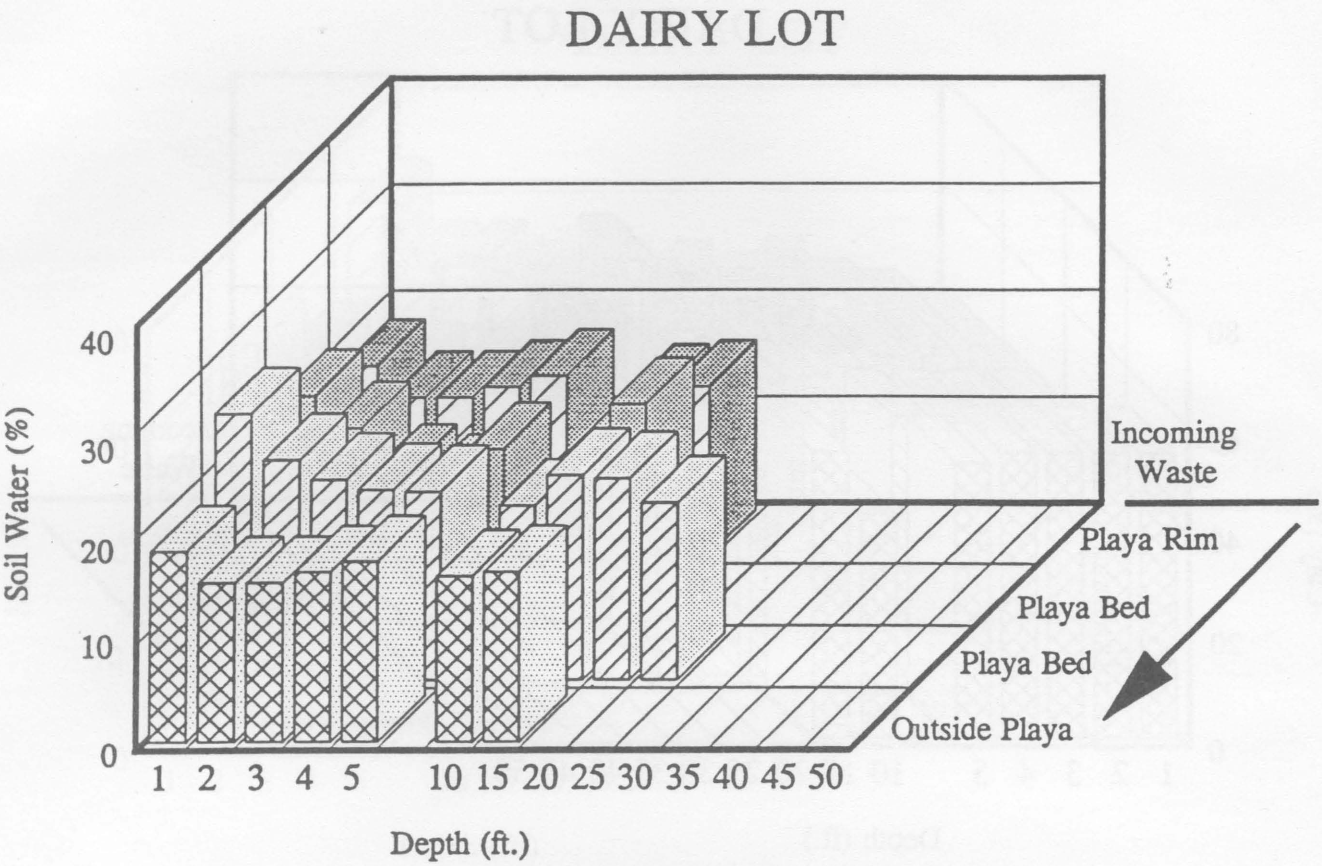


Figure 15. Clay concentrations in soil profiles at drill sites.



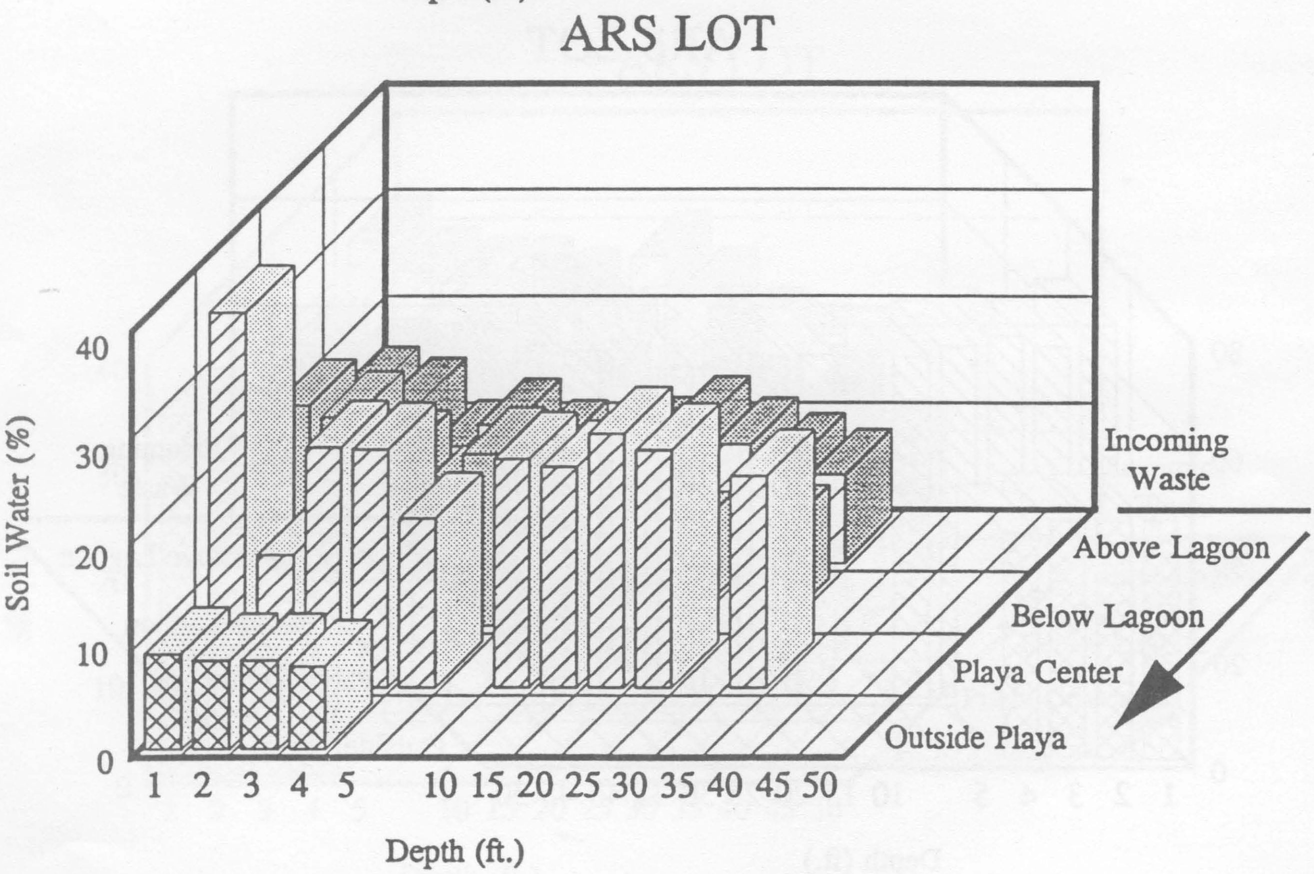


Figure 16. Water contents in soil profiles at drill sites.

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