UNIVERSIDAD DE PUERTO RICO

RECINTO DE MAYAGUEZ

Final Technical Report

of the

Research

on

The use of a

Geographic Information System

and

Remote Sensing Technology

for

monitoring land use and soil carbon change

in the

subtropical dry forest life zone

of

Puerto Rico

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June 25, 1996

Dr. Armond T. Joyce
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Dear Dr. Joyce:

Enclosed please find the Final Technical Report of the Research on **The use of a Geographic Information System and Remote Sensing Technology for monitoring land use and soil carbon change in the subtropical dry forest life zone of Puerto Rico.**

Giving in advance my thanks to you and your related staff for the opportunity to collaborate with your agency in the concerned matter.

Cordially yours,

Linda L. Vélez Rodríguez
Associate Professor

Enclosure

TABLE OF CONTENTS

- Land Use and Land Cover 1995 Jobos Bay National Estuarine Research Reserve
- Land Use and Land Cover 1989 Guánica Commonwealth Forest
- Land Use and Land Cover 1983 Guánica Commonwealth Forest
- Land Use and Land Cover 1971 Guánica Commonwealth Forest
- Land Use and Land Cover 1963 Guánica Commonwealth Forest
- Land Use and Land Cover 1950-51 Guánica Commonwealth Forest
- Land Use and Land Cover 1936 Guánica Commonwealth Forest

Appendix 2: Bar Graphs of the Soil Samples Analysis

Appendix 3: Digital Soil Survey Maps and Soil Types Index

- Lajas Valley Soil Survey
- Ponce Soil Survey
- Humacao Soil Survey
- Lajas Valley Soil Types Index
- Ponce Soil Types Index
- Humacao Soil Types Index

Appendix 4: Fundamentals of Remote Sensing Workshop

- Fundamentals of Remote Sensing Workshop Schedule
- List of Participants at the Fundamentals of Remote Sensing Workshop during the week of July 10 to 14, 1995
- List of Participants at the Fundamentals of Remote Sensing Workshop during the week of August 7 to 11, 1995
- Evaluations Forms filled out by the participants

The use of a Geographic Information System and Remote Sensing Technology for monitoring land use and soil carbon change in the subtropical dry forest life zone of Puerto Rico

Abstract

Aerial photography, one of the first form of remote sensing technology, has long been an invaluable means to monitor activities and conditions at the Earth's surface. Geographic Information Systems or GIS is the use of computers in showing and manipulating spatial data. This report will present the use of geographic information systems and remote sensing technology for monitoring land use and soil carbon change in the subtropical dry forest life zone of Puerto Rico. This research included the south of Puerto Rico that belongs to the subtropical dry forest life zone. The Guánica Commonwealth Forest Biosphere Reserve and the Jobos Bay National Estuarine Research Reserve are study in detail, because of its location in the subtropical dry forest life zone.

As the primary source of data was used aerial photography, digital multispectral imageries, soil samples, soil survey maps, field inspections, and differential global positioning system (DGPS) observations. With the collected data was build a digital data base and relating it with a GIS.

The information provided in this report is a valuable tool in the development of priorities for the management of the natural resources which are under natural or man-induced stress. For the Jobos Bay National Estuarine Research Reserve, a land use and land cover map for the year of 1995 part of this report. Also for the Guánica Commonwealth Forest Biosphere Reserve a series of six land use and land cover maps for the year 1936, 1950-51, 1963, 1971, 1983, and

1989. Those maps will be useful to those interested in the historical development of this region of Puerto Rico.

Introduction

In accordance with the Ecological Life Zones of Puerto Rico and the United States Virgin Islands Map by J. J. Ewel and J. L. Whitmore scale 1:250,000 in which the Classification of World Life Zones or Plant Formation developed by L. R. Holdridge is used, most of the south part of Puerto Rico belongs to the subtropical dry forest life zone classification together with the east Ceiba, Ensenada Honda, Culebra, part of Vieques; and in the west Mona Island. In the south of Puerto Rico includes Guayama, Salinas, Santa Isabel, Coamo, Juana Díaz, Ponce, Guayanilla, Yauco, Guánica, and part of the municipalities of Lajas and Cabo Rojo.

The life zone are defined by mean annual values of the three major climatic factors of the environment, namely, heat, precipitation and moisture. However, it must be remembered that within a six-sided bar of the three dimensional life zone figure there may be a whole series of latitudinal and one basal life zone with identical biotemperature, precipitation and potential evapotranspiration range ratios. Additional climatic factors such as day length, atmospheric pressure and seasonal variations of radiation differentiate the life zones within each of those series. Quantitative values of those additional climatic factors are not needed on the diagram because they are correlated directly with mean annual biotemperatures and altitudes (Tosi, Jr. 1967). As the title of this report states, Geographic Information System (GIS) and Remote Sensing was used for monitoring land use and soil carbon change in the south part of Puerto Rico that belong to the subtropical dry forest life zone.

This final technical report covered a period of over fourth years of intensive research. The original proposal was for three years, but an extension was granted with two new activities for an extra year. During that period of time also the principal investigator was doing other endeavors that enhance the quality of this research. The result of the Land Use and Land Cover Maps Series of the Guánica Commonwealth Forest Biosphere Reserve (Guánica Forest) was finish, the maps and their analysis are part of this report. During fiscal year 1995, the principal investigator receive a one year grant (Award No. NA47OR0476) from the National Oceanic and Atmospheric Administration (NOAA) to develop a digital data base of the Land Use and Land Cover of the Jobos

Bay National Estuarine Research Reserve (Jobos Bay Reserve). These results are also part of this technical report.

With the detail study of these two important site within the Subtropical Dry Forest Life Zone of Puerto Rico, there are the Guánica Forest and the Jobos Bay Reserve, it will complement the unsupervised classification of the Airborne Ocean Color Imager digital image acquired in the NASA mission number 94-019, dated December 14, 1993. The Appendix 1 - Image Illustrations and Maps, shown all the maps and images mention before.

Materials and Method

Changes in forest cover over time are important because of the role forests play in the global carbon cycle, in global climatic trends, and in providing species habitat (Woodwell et al. 1984). Although understanding forest change is important worldwide, it is especially important in the tropics, where land use transformation is occurring very rapidly and where timely ground data are scarce. This research will provide a better understanding of global climate change, deforestation, global carbon budget and the impact of man on the environment.

Along the study area, soil samples were taken and analyzed at the Soil Conservation Service Soil Survey Laboratory at Lincoln, Nebraska. A summary of the analysis are included in the Appendix 2, as bar graphs with a list of the identification and it location. The area that belong to the subtropical dry forest life zone within the Lajas Valley, Ponce, and Humacao Soil Surveys were digitized. On Appendix 3 an index map for each soil survey and a list with the soil types are part of the appendix 3.

Jobos Bay Reserve

Jobos Bay National Estuarine Research Reserve is located on the southeastern coastal plain of Puerto Rico, within the subtropical dry forest life zone of Puerto Rico's tidal and submerged wetlands. Important wildlife habitats within the Reserve limits include coral reefs, extensive seagrass beds, sand beaches, fifteen small mangrove cays (known as Cayos Caribe) and the mangrove forest and lagoon areas of Mar Negro. Endangered species such as the West Indian manatee, hawksbill and green sea turtles, the brown pelican and the yellow shouldered blackbird live within the Reserve.

Jobos Bay Reserve and vicinity is subjected to different land use and land cover, which could be impacting its unique environmental characteristics. Examples of these include: extensive and intensive agricultural activity, thermoelectric power generation, sanitary landfills, residential areas, golf courses, and marinas. The ability to identify, quantify, and up-date these land use and land cover areas are valuable tools for future research and to ensure adequate management of the Reserve. Literature about land use and land cover of the Jobos Bay area is very scarce. The only reference available is Seguinot (1986).

A photointerpretation of a variety of aerial photography was used as a primary source of information for the land use and land cover classification. Black and White (B/W), Color prints and Color Infrared (CIR) transparencies were the primary photographic sensors used. The CIR transparencies were taken during the December 1993 NASA Mission flight 94-019-HR-732, which cover the USGS Topographic Quadrangles series of 7.5 minutes of Salinas and Central Aguirre at scale of 1:20,000, also was used. Those topographic quadrangles were used for georeferencing the data.

The land use and land cover designations followed the criteria of Mitchell et al. (1977), Milazzo (1980), and Anderson et al. (1976). Level 1 of the urban classification was the intensity identified in the aerial photography. Urban or build-up land is comprised of areas of intensive use with much land covered by structures. Forested wetland are wetlands dominated by woody vegetation. Forested wetland includes seasonally flooded bottom land hardwoods, mangrove swamps, shrub swamps, and wooded swamps including those around bods, Anderson et al. (1976). Nonforested wetlands are dominated by wetland herbaceous vegetation or are nonvegetated. These wetlands include tidal and nontidal fresh, brackish, and salt marshes and nonvegetated flats, brackish, and salt marshes and nonvegetated flats and also freshwater meadows, wet prairies, and open bogs, Anderson et al. (1976). Barren land is land of limited ability to support life and in which less than one-third of the area has vegetation or other cover. In general, it is an area of thin soil, sand, or rocks, Anderson et al. (1976). Agricultural land may be defined broadly as land used primarily for production of food and fiber, Anderson et al. (1976).

Some land use and land cover designations were modified to facilitate the mapping. For Forest land was used the open/closed forest designation of FAO (1993). Closed forests are forests whose canopies cover all the land surface and the

photointerpreter cannot see the forest floor. Open forests have open canopies and the photointerpreter can see the forest interior on the aerial photography. The Dry forest is a land use and land cover classification that was especially designated for this photointerpretation. Dry forests are forests of dry or brown bushes and dry grass in the slope of a hilly terrain. The Grass classification is a level 2 category of Agricultural land, where the texture of the aerial photography look smooth as grass. The Water classification are those polygons that follows in the categories of lakes (like Lago Melania) or ponds for agricultural purposes.

In summary, the different land use and land cover polygons include: Urban and build-up areas; Agricultural; Grass; Dry forest; Forest land open; Forest land closed; Forest and Non-forested wetland; Water; and Barren land. In addition to the photointerpretation, field inspections were performed. The location of the toll highway PR-53 and connecting roads was performed using differential global positioning system (DGPS) observations in a mobile mapping mode.

The conversion of the remote sensing data from the aerial photography to digital form is the foundation for the digital data base. As a GIS software, it was used PC Arc/Info version 3.4.2 develop by Environmental Systems Research Institute, Inc. of Redlands, California. For PC Arc/Info a coverage is a homogeneous class of data within a digital map, such as roads. In a coverage, map features are stored as simple points, lines, or polygons. Thematic descriptors, such as feature name, symbol, classification and any other desired attributes for each point, line, or polygon are stored in feature attribute tables. As part of the digital data base were developed the following coverages: Jobos, Carr1, Carr2, Rio, and Muni. A plotting file is the file for plot a digital map. The plotting file content the digital map entitle Land Use and Land Cover 1995 Jobos Bay National Estuarine Research Reserve, within all coverages mention previously.

Guánica Forest

Guánica Forest was declared part of the international network of biosphere reserves by the United Nations on October 2, 1981. Guánica Forest was studied in order to establish the standard to measure the effects of man's impact

on his environment in other parts of the south of Puerto Rico.

The Guánica Forest encompasses approximately 4,010 ha in the southwestern coast of Puerto Rico. The Guánica Forest is unique because its land use history is well known and forest vegetation has been studied extensively beginning in the 1920's (Gleason and Cook 1926). Other studies describe vegetation structure, productivity, and dynamics (Lugo et al. 1978, Murphy and Lugo 1986a, Lugo and Murphy 1986). Results of experiments involving perturbation of vegetation by cutting and applying herbicides are also available (Ewel 1971, Murphy and Lugo 1986a).

The northern, and western limits of the study area were delimited by the two USGS quadrangles (Guánica and Punta Verraco) that contained the Guánica Forest. These topographic maps were also used as base maps for the photointerpretation. The southern limit of the study area was the coast line. It was used all the aerial photography available for the region from the Photogrammetry Office of the Puerto Rico Highway and Transportation Authority. For the map labeled 1950 to 1951, two years are used because the photos were taken during December 1950 and January 1951.

Maps includes what could be seen in the photos. Close study of maps shows that some trails were shown in the 1950 to 1951 map but not in the others. This is because some of the trails were not clearly visible in some years. The charcoal pits were only visible in the 1936 photos. However, they are hard to detect and not all individual charcoal pits were mapped. Charcoal production in Guánica Forest ceased at the end of the 1940s.

The land use designations followed the criteria of Mitchell et al. (1977), Milazzo (1980), and Anderson et al. (1976). It was classified as urban or built up land anything that had concrete or tarmac and used their level 1 designation of the suggested urban classification protocol. Some land use designations were modified to facilitate the mapping and adapt protocols to the particular land uses of Guánica Forest. For forest cover we used the open/closed forest designation of FAO (1993). Closed forests are forests whose canopies cover all of the land surface and the photo interpreter could not see the forest interior on the aerial photo. Trees tend to have a wider spacing in open forest designation compared to closed forests. Field survey suggest that some open forests were disturbed forests in younger stage of development which over time, matured into closed

forests. Other open forests also occur were mature stages of forests growing under harsh edaphic conditions. These stands remained open forests for decades, even in the absence of disturbance.

Beachesand rocky shores are grouped as natural barren land. Mangroves are forested wetlands. Salt flats are grouped into the non-forested wetlands category. However, these salt flats can flood, in which case they were interpreted as water. The timing of rains relative to the time of the photography can thus affect the interpretation of the land use. Quarries and sanitary land fills were classified as artificial barren lands. The category other barren lands included abandoned house and baseball park sites now being studied by S. Molina, and cutting and herbicide experiment conducted by Ewel (1971).

Once the base maps were finalized, they were digitized. Areas under each land use within and outside of the forest boundary as well as for all the study area were estimated for each map. Table 2 shows each land use and land cover classification with their total area in hectares, within forest boundary, outside forest boundary and all Guánica. PC Arc/Info was used for the digitalization and all the analyses.

Subtropical Dry Forest Life Zone

The image illustration entitle AOCI Puerto Rico Subtropical Dry Forest Life Zone show the Airborne Ocean Color Imager (AOCI) Rawdata, each band wavelength in micrometer and a color composite of the area using three bands. The AOCI is a high altitude multispectral scanner designed for oceanographic remote sensing. It provides 10-bit digitization of eight bands in the visible/near infrared region of the electromagnetic spectrum, plus two 8-bit bands in the near and thermal infrared. The ground resolution at an altitude of 65,000 feet is equal to 163 feet(50 meters).

The unsupervised classification is when the computer separates the pixels into classes with no direction from the analyst. The unsupervised classification of the AOCI image of the south of Puerto Rico results are shown in the Image Illustrations entitle Land Use Classification Puerto Rico Subtropical Dry Forest Life Zone. Using the same unsupervised classification of the AOCI image of the subtropical dry forest life zone of Puerto Rico where encompass the Guánica Forest and the Jobos Bay Reserve were enlarged. The ELAS program was used for the unsupervised

classification, automatically defined 25 classes for the scene. After the 25 unsupervised classes were calculated, each class was displayed for inspection, after that, was combined various categories into the six classes shown in the Image Illustrations, there are: Forest, water, urban, bare soil, agricultural/pasture and clouds.

The general distribution of the patterns of the Image Illustration -Land Use Classification-Guánica Commonwealth Forest and Land Use Classification - Jobos Bay National Estuarine Research Reserve are similar to the patterns of the photointerpretation of the maps of Land Use and Land Cover 1989 Guánica Commonwealth Forest and Land Use and Land Cover 1995 Jobos Bay National Estuarine Research Reserve, although the output of 1989 and 1995 have more detail in there classes.

Results

It can be pointed out that the general distribution of the patterns of the Image Illustration - Land Use Classification - Guánica Commonwealth Forest and Land Use Classification - Jobos Bay National Estuarine Research Reserve are similar to the patterns of the photointerpretation of the maps of Land Use and Land Cover 1989 Guánica Commonwealth Forest and Land Use and Land Cover 1995 Jobos Bay National Estuarine Research Reserve, although the output of 1989 and 1995 maps have more detail in there classes than the Image Illustrations.

The prevailing land use and land cover classification on the Jobos Bay Reserve area (area within the Salinas and Aguirre USGS Quadrangles) was agricultural land, followed by urban or build-up land. Table 1 shows each land use and land cover classification with their total area in hectares. Figure 1 shows the percentage distribution of each land use and land cover polygon of the Jobos Bay National Estuarine Research Reserve (JBNERR).

A color map entitle Land Use and Land Cover 1995 Jobos Bay National Estuarine Research Reserve is a hard copy of the plotting file. This plotting file was plot on a 8 1/2" by 11" paper, but the fonts are design for a plot on a 24" by 36" paper.

For each of the six Land Use and Land Cover Maps of Guánica Forest there will be a quantitative analyses, for each one of the land use and land cover classification on

table 2. Also the total forest cover designation is the sum of open and closed forests, forested wetlands, and tree plantations. Total natural vegetation was total tree cover plus non-forested wetlands. Natural areas was the total of natural vegetation, natural barren land, and water. Converted lands was the sum of artificial barren lands, other barren lands, urban or built-up lands, and agricultural lands.

Table 1. Land Use Classification of the Jobos Bay Study Area

Land use	Area (hectares)
Agricultural land	8,715,440
Barren land	256,260
Urban and build-up areas	1,525,920
Grass	98,360
Water	71,720
Dry forest	1,137,220
Forest land open	234,080
Forest land closed	280,970
Forest wetland	1,256,530
Non-forested wetland	219,390

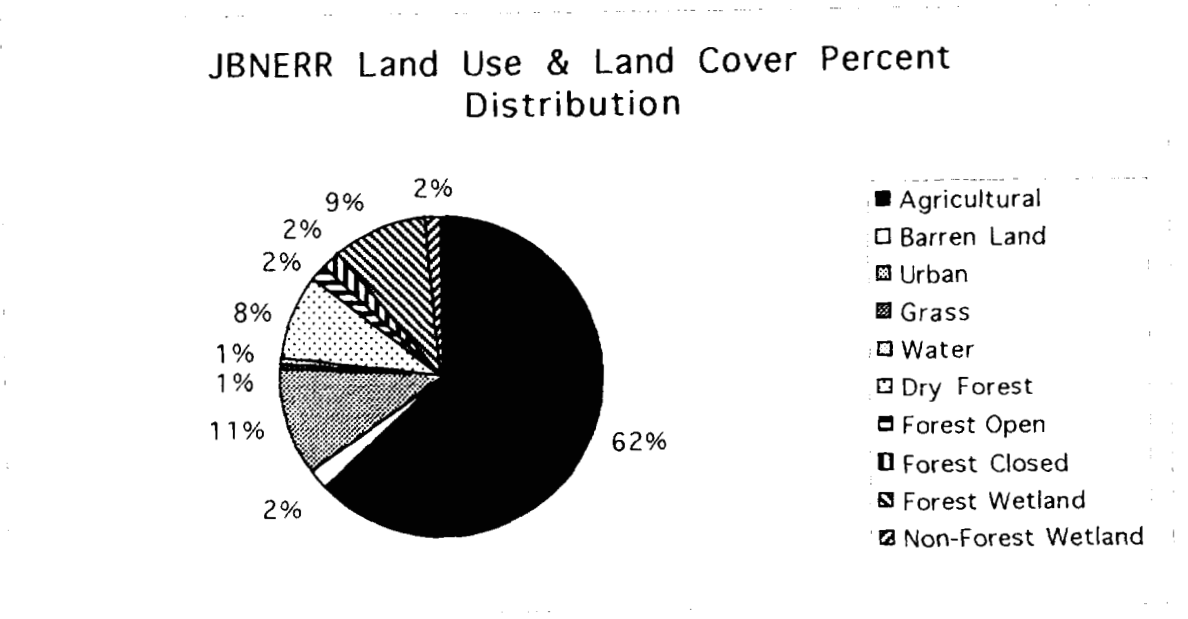
JBNERR Land Use & Land Cover Percent Distribution
2%
9%
2%
2%
8%
1%
1%
11%
2%
62%
Agricultural
Barren Land
Urban
Grass
Water
Dry Forest
Forest Open
Forest Closed
Forest Wetland
Non-Forest Wetland

Figure 1

Land use	1936	1950	1963	1971	1983	1989
Within forest boundary						
Urban or built-up land	0.26	3.54	4.87	4.48	3.75	9.46
Agricultural land	151.29	73.89	14.15	21.89	2.47	3.77
Water	0.65	2.28	2.61	2.41	2.60	2.67
Forest land (open)	1442.66	1007.83	471.84	291.61	138.69	122.15
Forest land (closed)	11724.45	2249.76	2865.34	3038.79	3204.69	3220.16
Plantations	13.65	0.22	0.95	0.97	0.00	0.64
Forested wetland	7.81	11.53	10.01	9.18	8.46	10.38
Non-forested wetland	0.01	0.00	0.24	0.00	0.06	0.00
Natural barren land	25.72	12.21	2.85	12.46	12.37	17.82
Artificial barren land	1.40	8.84	8.14	1.41	9.59	0.00
Other barren land	15.09	14.26	0.01	1.31	0.78	1.12
Total forest cover	3188.58	3269.33	3348.14	3340.55	3351.84	3353.33
Total natural vegetation	5124.59	5219.33	5311.38	5311.55	5334.90	5342.33
Total natural areas	5150.96	5233.82	5316.84	5326.42	5349.87	5362.82
Total converted areas	168.04	100.52	27.18	29.10	16.58	14.35
Outside forest boundary						
Urban or built-up land	135.89	220.03	384.89	488.29	689.22	699.37
Agricultural land	3365.90	3091.77	3037.49	3241.72	2568.38	1795.44
Water	150.04	156.72	26.24	17.04	20.61	23.01
Forest land (open)	671.49	561.25	578.51	473.3	180.50	1119.37
Forest land (closed)	1456.62	1696.11	1668.89	1621.44	2394.27	2281.51
Plantations	27.97	34.81	34.98	33.78	26.24	23.64
Forested wetland	54.74	57.87	66.73	68.25	69.32	77.49
Non-forested wetland	83.13	73.02	103.54	91.74	77.11	58.22
Natural barren land	77.37	30.39	28.31	16.2	17.01	15.09
Artificial barren land	30.09	99.36	183.14	50.75	45.13	11.66
Other barren land	72.96	82.72	23.73	10.76	35.48	18.05
Total forest cover	2210.81	2350.04	2349.11	2196.78	2670.34	3502.01
Total natural vegetation	2293.94	2423.07	2452.65	2288.52	2747.45	3560.23
Total natural areas	2521.35	2610.17	2507.21	2321.76	2785.07	3598.33
Total converted areas	3605.84	3493.88	3629.25	3791.51	3338.22	2524.52
All Guánica						
Urban or built-up land	136.15	223.57	389.76	492.77	692.97	708.83
Agricultural land	3517.19	3165.66	3051.64	3263.61	2570.85	1799.21
Water	150.69	158.99	28.86	19.45	23.21	25.68
Forest land (open)	2114.15	1569.08	1050.34	764.92	319.2	1241.52
Forest land (closed)	3181.07	3945.87	4534.23	4660.22	5598.96	5501.68
Plantations	41.63	35.03	35.93	34.76	26.24	24.28
Forested wetland	62.54	69.40	76.75	77.43	77.78	87.86
Non-forested wetland	83.14	73.02	103.78	91.74	77.17	58.22
Natural barren land	103.09	42.60	31.16	28.66	29.38	32.91
Artificial barren land	31.49	108.20	191.28	52.16	54.72	11.66
Other barren land	88.05	96.98	23.75	12.07	36.60	19.16
Total forest cover	5399.39	5619.38	5697.25	5537.33	6022.18	6855.34
Total natural vegetation	5482.53	5692.40	5801.03	5629.07	6099.35	6913.56
Total natural areas	5736.31	5894.00	5861.04	5677.18	6151.95	6972.15
Total converted areas	3772.87	3594.41	3656.43	3820.61	3354.80	2538.86

Table 2. Area of the land use categories within and outside Guánica Forest and in all the area of the study in the quadrangles of Guánica and Punta Verraco between 1936 and 1989. All values are in hectares. Text defines each land use.

In 1936, the main land use within the boundary of Guánica Forest was closed forest, followed closely by open forest (Table 2). There were 151 ha of agricultural lands within the forest boundary. Outside the forest boundary, the main activity was agriculture with closed forests representing half as much area as agriculture. Urban land use was 136 ha. Agriculture was the major land use in the region as a whole, followed in order by closed forest, open forest, water, and urban land use (Table 2).

During the 1936 time period, the prevailing forest type in the eastern portion of the Guánica Forest was open forest. Canyon vegetation is clearly delimited as closed forest and can be identified by the north-south orientation of the canyons, which are drainage channels during storm periods. Most charcoal pits were located within the matrix of open forest and were easier to detect than in later periods. Near the northern limit of the eastern portion of Guánica Forest appears a large tree plantation of *Haematoxylon campechianum*. Closed forest areas are concentrated north of Guánica Forest boundary and on the western limits of the 1936 maps. Urban uses were concentrated around the town of Guánica and the sugar mill at Ensenada, both to the west of the Guánica Forest. Forested and non-forested wetlands are all coastal. The large coastal plantation south of the boundary of the Guánica Forest, was a coconut plantation. A portion of Guánica Lagoon is visible on the north-west portion of the 1936 map. The Bay surrounded by urban and wetland (forested and non-forested) uses is Guánica Bay.

By 1950, the area of closed forest increased within Guánica Forest while open forest and agricultural land decreased (Table 2). Urban built-up land multiplied 13 fold to 3.5 ha. The dominant land uses outside Guánica Forest retained their 1936 ranking, but had a different absolute areas. However, closed forest became the dominant land use for the study area and exceeded the area of agricultural lands by 1,000 ha. During this period there was also a dramatic increase in the area of artificial barren land and a reduction in the area of natural barren land.

The 1950-51 map shows the expansion in area of the Guánica Forest. After 1950, Guánica Forest had a western and eastern sector with Guánica Bay and other public lands in between. This land use map illustrates the expansion of closed forest at the expense of what was open forest in 1936. The eastern and western portions of Guánica Forest east of Guánica Bay, were areas of rapid change from open to closed forest with charcoal pits in 1936, appears as open forest.

The changes in land use in the western portion of the Forest were not as dramatic as those in its eastern portion. On the northwest sector south of Guánica Lagoon, one can notice the expansion of closed forest and open forest at the expense of agricultural land. The Guánica Lagoon was invaded by agricultural land use. Large areas of barren lands appear on the east and north central portions of the 1950-51 map. Around the Guánica Bay one can see a small expansion of urban land and a large expansion of agricultural lands. Other barren lands decreased in area near the Guánica Bay and were converted to urban use. There is also urban land expansion on the northeast of the map area. Agricultural land use remained constant on the northwestern central region of the map.

There were no dramatic changes in the rank order of land uses within the Guánica Forest between 1950 and 1963 (Table 2). However, agricultural land use was reduced from 74 to 14 ha. Outside Guánica Forest, agricultural lands remained constant in area and were the dominant land use. The most dramatic land use change was the reduction of water as a result of the drainage of Guánica Lagoon, which disappeared. The Commonwealth Government of Puerto Rico drained the lagoon to use its bottomland for agriculture. Non-forested wetland area also increased between 1950 and 1963. The rank order of the top five land uses for the region as a whole remained the same in 1963 as it was in 1950, with closed forest being the dominant land use.

The 1963 map, reflects the consolidation of closed forest over most of the eastern portion of Guánica Forest. Pockets of open forest remain on the southern portion of Guánica Forest. Some of these pockets are associated with limestone outcrops with very thin soils which cannot support closed forest (Lugo et al. 1978). Open forest in 1963 had also invaded lands under agricultural use in 1950, i.e., north of the Guánica Bay. Urban uses increased around the town of Guánica, but also appear near the boundary of Guánica Forest northeast and north of the town of Guánica. Urban expansion also occurred to the northeast of the 1963 map, and inside Guánica Forest (the house of the forest guard and as facilities in the public beach, Caña Gorda). Large artificial barren lands appear on the western central portion of the 1963 map. The Guánica Lagoon disappeared in this map and its land was used for agriculture. Coastal wetlands and salt flats (natural barren lands) show interesting dynamics (between 1936 to 1963) just west of the town of Guánica on the north shore of Guánica Bay, and just west of the coconut

plantations and east of Caña Gorda Beach (south central shore of the Guánica Forest). Cintrón et al. (1978) contains soil salinity data and describe periodic disturbances that explain these wetland dynamics.

By 1971, closed forest became an overwhelming dominant land use inside Guánica Forest (Table 2). Other land use remained minor in area, with the exception of open forest with some 292 ha which was ten times smaller than the area of closed forest. Outside the Guánica Forest boundary, agriculture and closed forest remained the main land uses (agriculture had twice the land as closed forest), but the urban area exceeded by a small margin the area of open forest. Nevertheless, the area under urban use remain lower than the area of open forest on the region as a whole.

The area of closed forest on the northwest portion of the study area reverted back to open forest. A long strip of closed forest land on the northwest boundary of the 1971 map, also reverted to open forest. Moreover, a long strip of open forest appeared just at the boundary of the municipalities of Guánica and Lajas, on what was agricultural lands. Urban areas continued to expand with new pockets appearing on the north and northeastern sectors outside Guánica Forest. Lands west of Guánica Bay, classified as open forest in 1963, were transformed to closed forest in 1971. In that region of the map, lands that were classified as urban in 1963, reverted to agricultural land in 1971, one of the few instances when this land use transformation occurred. A hectare used in research on forest dynamics (Ewel 1971) is visible in the center of the eastern portion of the Guánica Forest and was classified as "other barren land".

By 1983, agricultural land reach a minimum area (2.5 ha) and urban land use was reduced inside Guánica Forest. Closed forest remain the dominant land use, with all other land uses covering small land areas (Table 2). Agricultural land was reduced in area, closed forest increased in area, and urban use had a dramatic increase outside the Guánica Forest boundary. In the region as a whole, closed forest land increased and continued to dominate the region's land use. Agricultural land use decreased and urban land area increased. Open forest reached a low area of 319 ha.

In 1983, the geographic expansion of closed forest at the expense of open forest and agricultural land reached a peak. Only scattered open forest areas are visible in the 1983 map and they correspond mostly to limestone outcrops. On the northwestern portion of the map, the large area of

open forest in 1971, reverted to closed forest. Urban areas expanded considerably; mostly towards the west of the region, but also near Yauco on the east, and around Caña Gorda on the south. A large area of barren land developed south of an urban area in the central portion of the map. The agricultural lands that had substituted the urban area in 1971, was converted to open forest in 1983. Closed forest developed behind the salt flat west of the town of Guánica, and a small patch of closed forest is seen inside the salt flats. This closed forest patch developed from an open forest patch that occurred there in 1971.

In 1989, the main land use inside Guánica Forest was closed forest (Table 2), distantly followed by open forest. All other land uses covered a small land area (40 ha). Closed forest exceeded agricultural land as the main land use outside Guánica Forest. Open forest was third in area with an increase of 939 ha relative to 1983. The other main land use outside the forest boundary was urban. For the region as a whole, the rank order of land uses was the same as that outside Guánica Forest: closed forest > agriculture > open forest > urban. Artificial barren land decreased to 12 ha.

In the 1989 map, a large fraction of agricultural land on the north west of the study area was converted to open forest. The large narrow strip of land on the western boundary which was open forest in 1971, appeared as closed forest in 1989. Most of the land mass south of the Guánica Forest northern boundary was closed forest with very few pockets of open forest. Urban areas grew and small patches consolidated into larger areas in many instances. The strip of mangroves on the north shore of Guánica Bay, west of the town of Guánica, reached its maximum thickness. The original (1936) mass of agricultural land was fragmented into three large segments to the west, north central, and eastern sector of the study area.

Discussion

The hills of the Guánica Forest vicinity and much of the Guánica Forest are underlain by the Ponce limestone, a Mid-Tertiary, pink to white, fine grain limestone. In addition, alluvial and colluvial deposits occur in valleys and at the bases of the low-lying hills. Soils in the area distinguished by parent material, rock content, and pedon thickness (Roberts 1942). The most common soil in Guánica Forest and adjacent area included in the land use maps is a dark to grayish brown, friable pedon derived from relatively soft

limestone. These calcimorphic soils were originally classified in the Rendzina Great Soil Group and were considered to have "low agricultural value and low carrying capacity" (Roberts 1942). More recently, soils in experimental plots within the Guánica Forest have been grouped into the mollisol soil order (Murphy and Lugo 1990). These soils have a high pH (7.8), relatively high organic matter content (18 to 23 percent), and occur in areas were 25 percent of the ground surface is exposed rocks. Soil creep within these pedons maybe limited to the upper soil profile and while it is a relatively slow process, measured creep rates are comparable to creep rates observed in other mid-latitude dry lands (Lewis 1975).

The trends in land use and land use change in the study area are very clear. Urban use and natural vegetation have increased steadily at the expense of agricultural and barren land. Forests changed from open to closed and mangrove forests expanded in area. The fraction of barren land decreased over the period of study. These changes reflect significant changes in the economy of the area. The transition from an agrarian to an urban society is perhaps the main causal agent of land use change in the region. When agriculture was the prevalent human activity in the region (period of 1936 to 1971), forests were open, and charcoal pits and exposed barren lands were a conspicuous aspect of the landscape. Roads, trails, and tree plantations were also plainly visible while urban areas were a low fraction of the landscape. Large-scale activities such as draining of Guánica Lagoon took place during this time.

The decline of agricultural activity unleashed rapid trends of land use change that included the increase in urban area, the maturing of open forests towards closed forests, the expansion wetlands, and the reduction of barren lands. For example, the decline in agricultural activity is usually associated with increases in mangrove areas because of abandonment of drainage canals along the coastal areas. The result is the restoration of hydrological conditions favorable for the expansion of mangroves.

Areas that were under agriculture in 1936 were used for a variety of land uses in 1989. After 53 years, 45 percent of these lands remained in agriculture and 43 percent had been converted to either open or closed forests. Twelve percent of these relatively fertile agriculture lands had been urbanized by 1989.

In 1936, agriculture within the present forest boundary was found on 5 different soil types. Sixty nine percent of this agriculture was on Aguilita clay, a shallow, dark to grayish brown, friable soil derived from soft limestone (Soil Type 17 of Roberts 1942). The Ensenada clay (type 14), a shallow, red, friable soil derived from limestone, supported 27 percent of the 1936 agriculture. Both of these soils were not considered suitable for cultivated crops and were recommended for cattle pasture or charcoal production. By 1989, forest occurred on all the soil types that had agricultural on them in 1936. This suggests that if the opportunity and time are available, dry forest vegetation can be restored on a diversity of soils, even those considered relatively infertile. Moreover, soil type is not an impediment to the restoration of this forest ecosystem.

The rates of land use change were higher inside Guánica Forest compared to outside the Forest. The transition towards a natural landscape was much faster under the protection of Guánica Forest than it was outside, where agricultural and urban use of the land remained active. However, the landscape as a whole changed towards a more natural state with more mature vegetation as a result of the protection management of the Guánica Forest and the doubling of the protected forest area.

There were alarming land uses changes between 1983 and 1989, which have exacerbated in recent years. The area of closed forest decline and that of open forest increased. Open forest tends to increase after agricultural lands are abandoned or when closed forest is disturbed. In Guánica Forest area, forest lands are being converted to urban uses, a trend that places mature vegetation in closed proximity to intensive urban uses. These intensive urban uses are associated with abundance of exotic species, including feral mammals that endanger mature forest wildlife such as the mariquita and guavairo, both endangered species. Clearly the boundary of the Biosphere Reserve requires protection by buffer zones of land uses that slowly increase in intensity with distance from the central core of mature vegetation inside Guánica Forest (cf. Lugo 1990, Canals Mora 1990).

Fundamentals of Remote Sensing Workshop

With the idea of spread the interest and knowledge of the fundamentals of Remote Sensing within the future Land Surveyors, a workshop for the students of the Land Surveying Program and others students of the Mayagüez Campus was offered during the summer of 1995. This fundamentals of Remote Sensing Workshop (FRSW) was presented in two session

for a maximum of ten students in each one, with a duration of five days of 7.5 hours per day each session.

This FRSW was presented by two instructors, the principal investigator of this project and professor José L. Flores Malavé, both from the Land Surveying Program of the Civil Engineering Department. The participants received a remuneration in addition to the experience and knowledge. The workshop was announce in the bulletin board on campus, and by mail to the Land Surveying students. The selection was based on the student grade point average and in an essay where he or she was demonstrated their interest. The two session where on July 10 to 14, 1995 and August 7 to 11, 1995 at the facilities of the Land Surveying Laboratory. A list of participants for each session are part of Appendix 4.

The topics that was covered during the FRSW are presented on the schedule in the Appendix 4. A field trip to the Guánica Forest was offered at the middle of the week. so they were able to correlate the research with the reality. The copies of the evaluation forms filled out by each participant of the FRSW are also included in the Appendix 4.

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Appendices

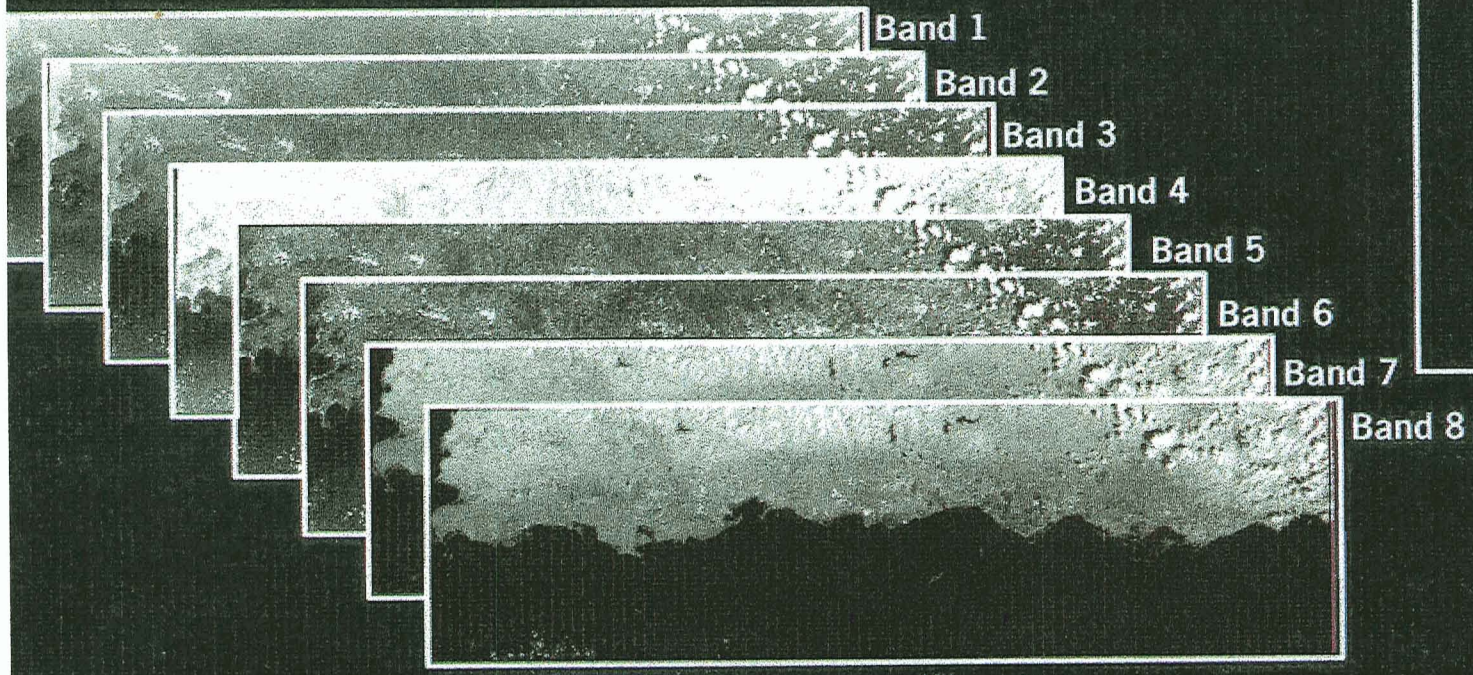
Appendix 1: Image Illustrations and Maps

- Airborne Ocean Color Imager (AOCI) - Puerto Rico Subtropical Dry Forest Life Zone
- Land Use Classification - Puerto Rico Subtropical Dry Forest Life Zone
- Land Use Classification - Guánica Commonwealth Forest
- Land Use Classification - Jobos Bay National Estuarine Reserve
- Land Use and Land Cover 1995 Jobos Bay National Estuarine Research Reserve
- Land Use and Land Cover 1989 Guánica Commonwealth Forest
- Land Use and Land Cover 1983 Guánica Commonwealth Forest
- Land Use and Land Cover 1971 Guánica Commonwealth Forest
- Land Use and Land Cover 1963 Guánica Commonwealth Forest
- Land Use and Land Cover 1950-51 Guánica Commonwealth Forest
- Land Use and Land Cover 1936 Guánica Commonwealth Forest

Airborne Ocean Color Imager (AOCI)

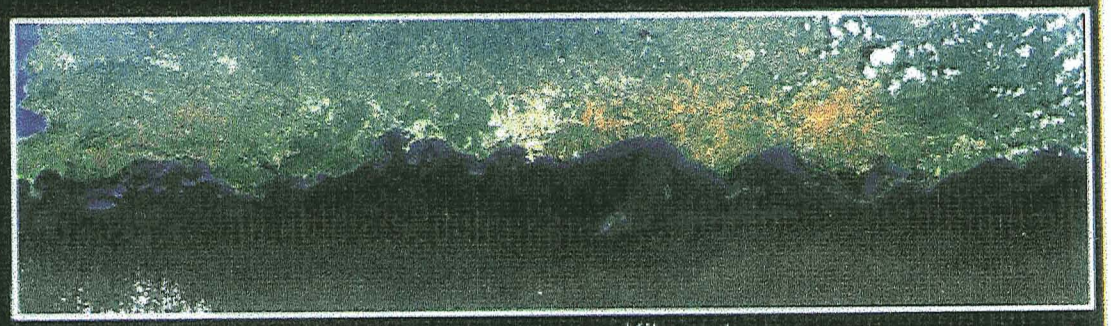
Puerto Rico Sub Tropical Dry Forest Life Zone

AOCI - Rawdata



Wavelength, Micrometer
0.436 - 0.455
0.481 - 0.501
0.511 - 0.531
0.554 - 0.575
0.610 - 0.631
0.655 - 0.676
0.741 - 0.800
0.831 - 0.897

Color Composite Bands 6,5,3 (R,G,B)

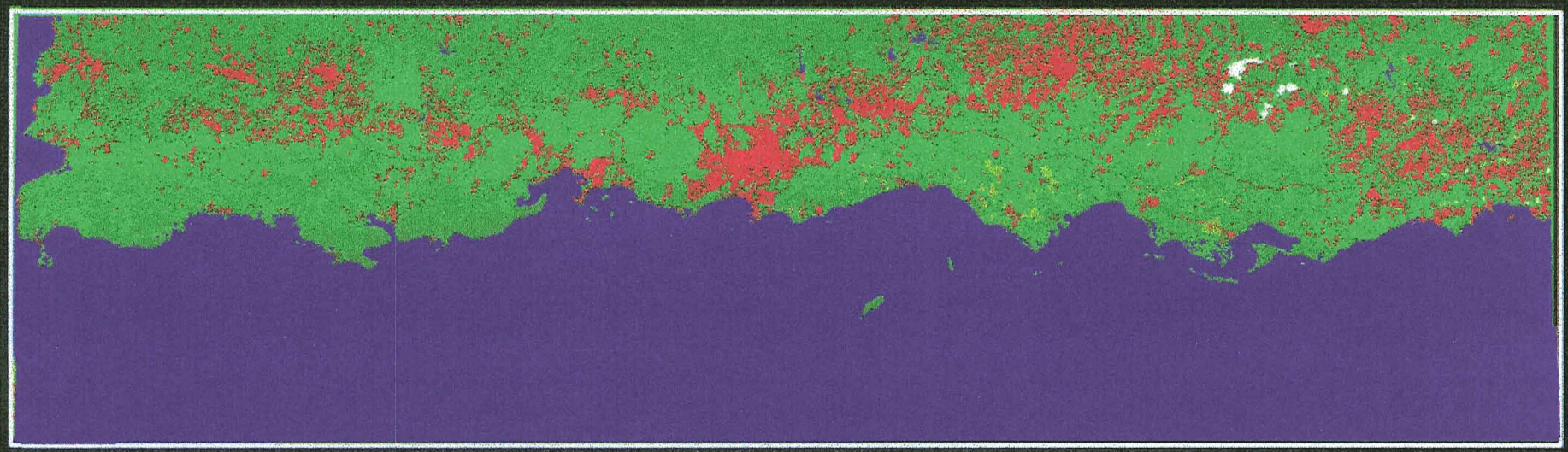


Source: Airborne Ocean Color Imager (AOCI)
Mission No. 94-019
Date Acquired: December 14, 1993
Software: ELAS and ERDAS/IMAGINE

Research Grant NAG13-17

Land Use Classification

Puerto Rico Sub Tropical Dry Forest Life Zone



Source: Airborne Ocean Color Imager (AOCI)
Mission No. 94-019
Date Acquired: December 14, 1993
Unsupervised - Maximum Likelihood
Software: ELAS and ERDAS/IMAGINE

Forest
Water
Urban
Bare soil
Agricultural / Pasture
Clouds

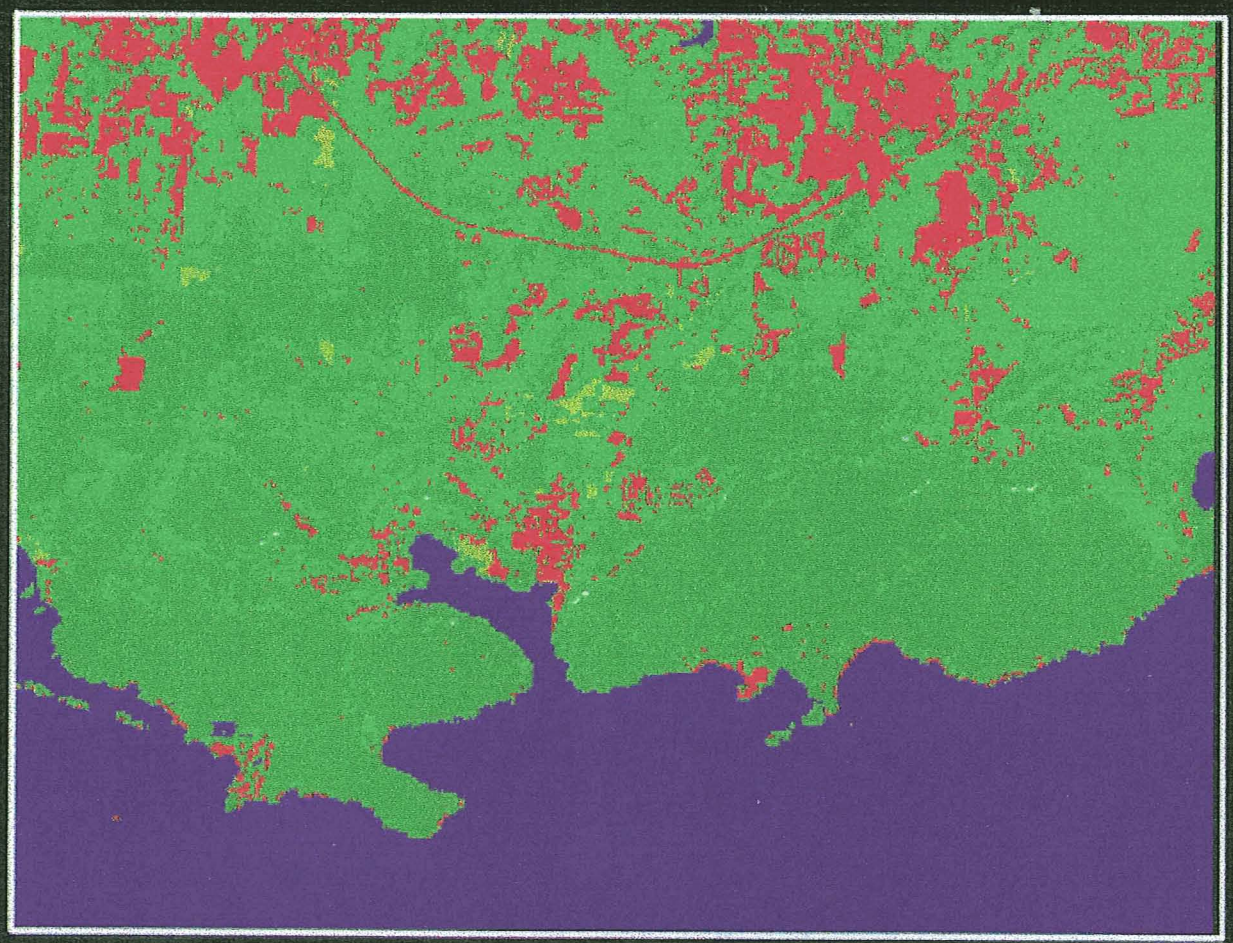
20 0 Kilometers

N

Research Grant NAG13-17

Land Use Classification

Guanica Commonwealth Forest



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Mission No. 94-019
Date Acquired: December 14, 1993
Unsupervised - Maximum Likelihood
Software: ELAS and ERDAS/IMAGINE

0 5 Kilometers

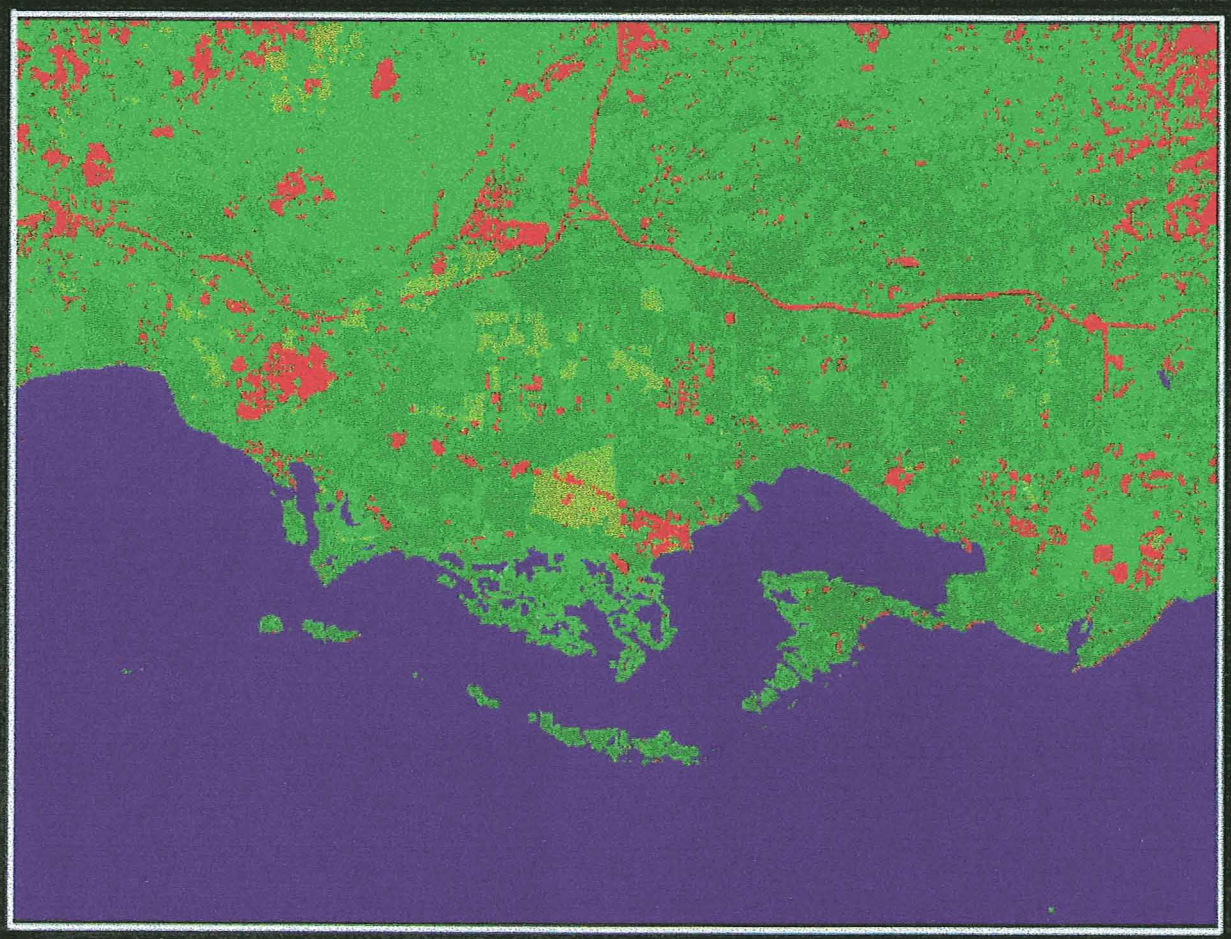
N

- Forest
- Water
- Urban
- Bare Soil
- Agricultural / Pasture

Research Grant NAG13-17

Land Use Classification

Jobos Bay National Estuarine Reserve



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Software: ELAS and ERDAS/IMAGINE

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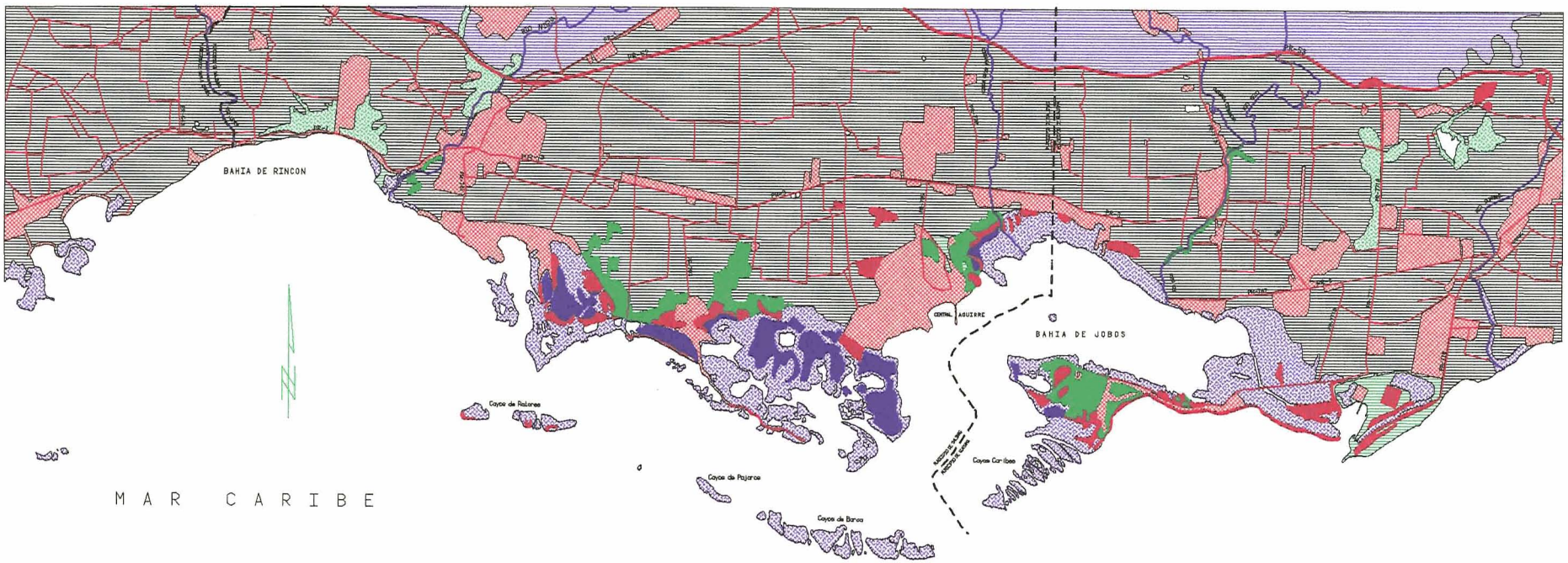
- Agricultural / Pasture

NASA

Research Grant NAG13-17



POLYGON LEGEND

- AGRICULTURAL LAND
- BARREN LAND
- URBAN OR BUILT-UP LAND
- GRASS
- WATER
- DRY FOREST
- FOREST LAND OPEN
- FOREST LAND CLOSED
- FORESTED WETLAND
- NON FORESTED WETLAND

LINEAR FEATURE LEGEND

- TOLL HIGHWAYS
- STREETS AND ROADS
- MUNICIPALITY BOUNDARIES
- RIVERS

SOURCES

- NASA Mission Flight 94-019-HR-732 CIR
- FIELD INSPECTION
- GPS DATA GATHERING ON TOLL HIGHWAY PR-53

SCALE 1:110,000

LAND USE AND LAND COVER 1995 JOBOS BAY NATIONAL ESTUARINE RESEARCH RESERVE

By
PROF. LINDA VELEZ RODRIGUEZ
UNIVERSITY OF PUERTO RICO
MAYAGUEZ CAMPUS
MAYAGUEZ, PUERTO RICO 00681-5000

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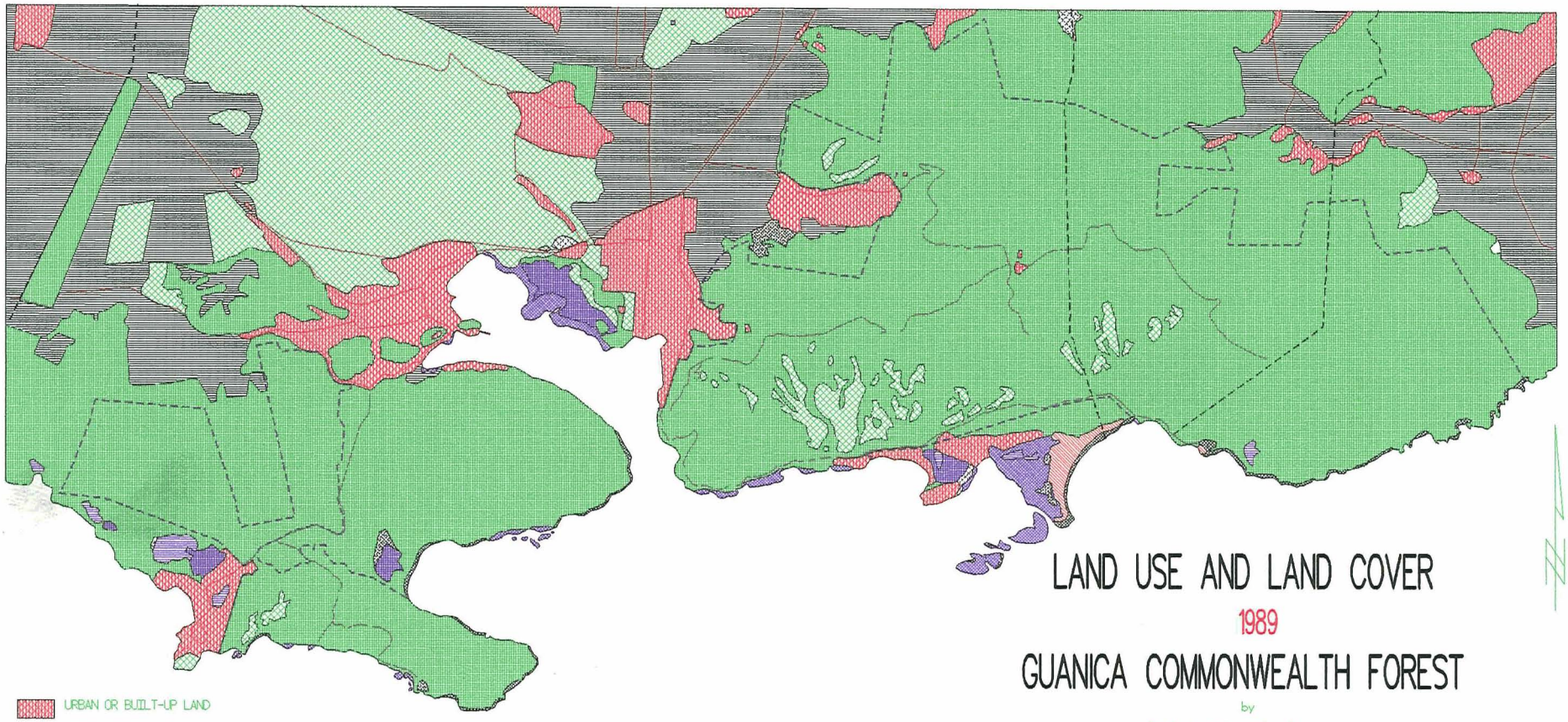

LAND USE AND LAND COVER

1989

GUANICA COMMONWEALTH FOREST

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- URBAN OR BUILT-UP LAND
- AGRICULTURAL LAND
- WATER
- FOREST LAND (OPEN)
- FOREST LAND (CLOSED)
- PLANTATIONS
- FORESTED WETLAND
- NONFORESTED WETLAND
- NATURAL BARREN LAND
- ARTIFICIAL BARREN LAND
- OTHER BARREN LAND

- LAND USE AND LAND COVER
- STREETS, ROADS AND HIGHWAYS
- MUNICIPAL BOUNDARIES
- FOREST BOUNDARIES

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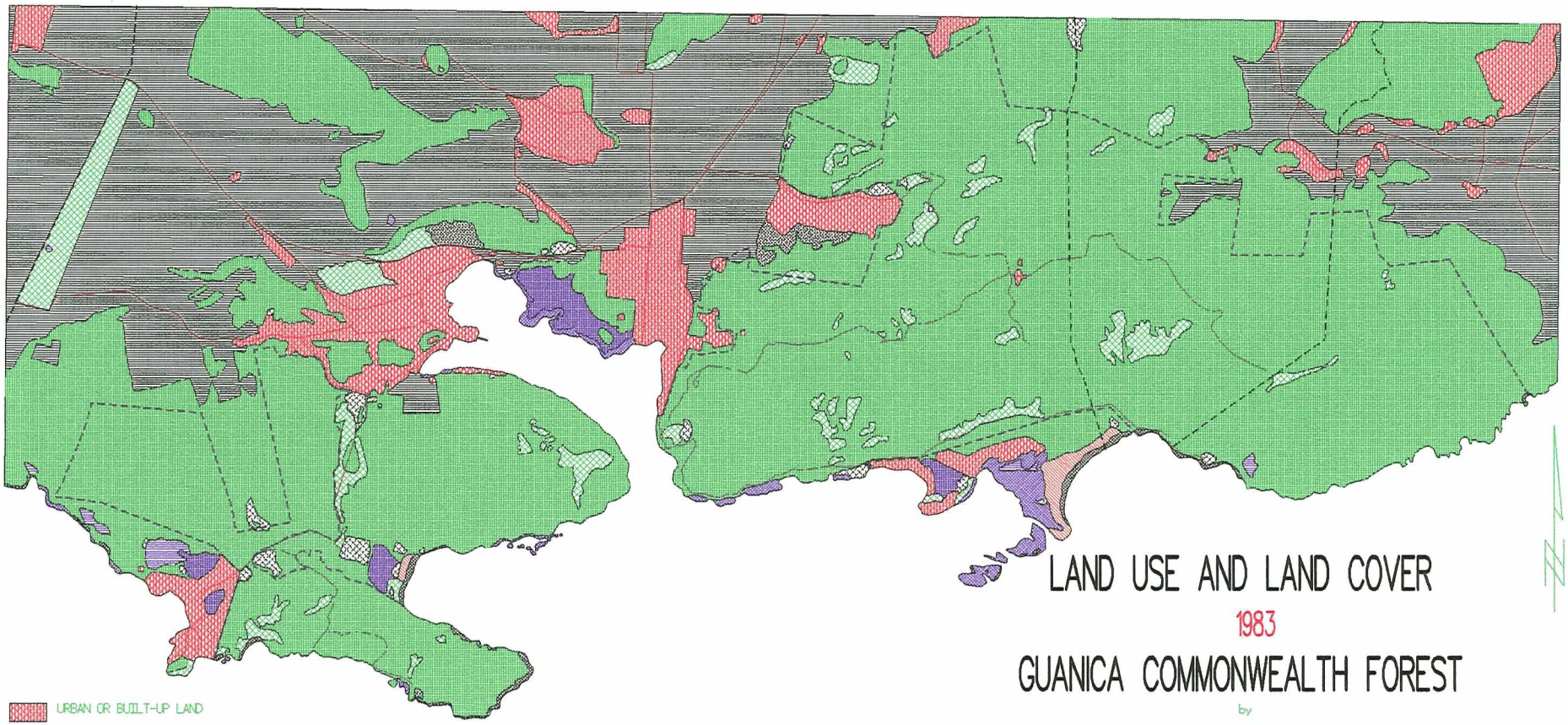

LAND USE AND LAND COVER

1983

GUANICA COMMONWEALTH FOREST

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AGRICULTURAL LAND
WATER
FOREST LAND (OPEN)
FOREST LAND (CLOSED)
PLANTATIONS
FORESTED WETLAND
NONFORESTED WETLAND
NATURAL BARREN LAND
ARTIFICIAL BARREN LAND
OTHER BARREN LAND

LAND USE AND LAND COVER
STREETS, ROADS AND HIGHWAYS
MUNICIPAL BOUNDARIES
FOREST BOUNDARIES

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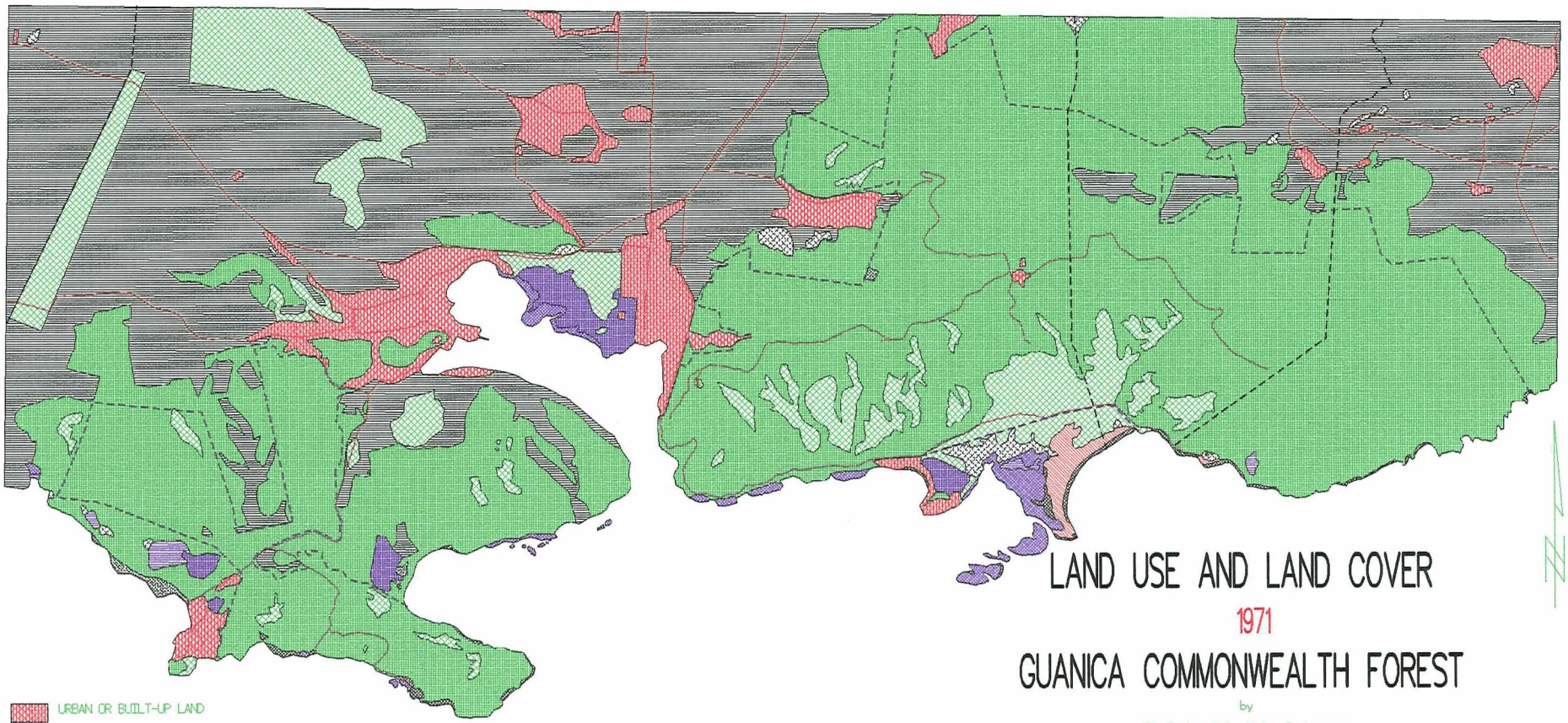

LAND USE AND LAND COVER

1971

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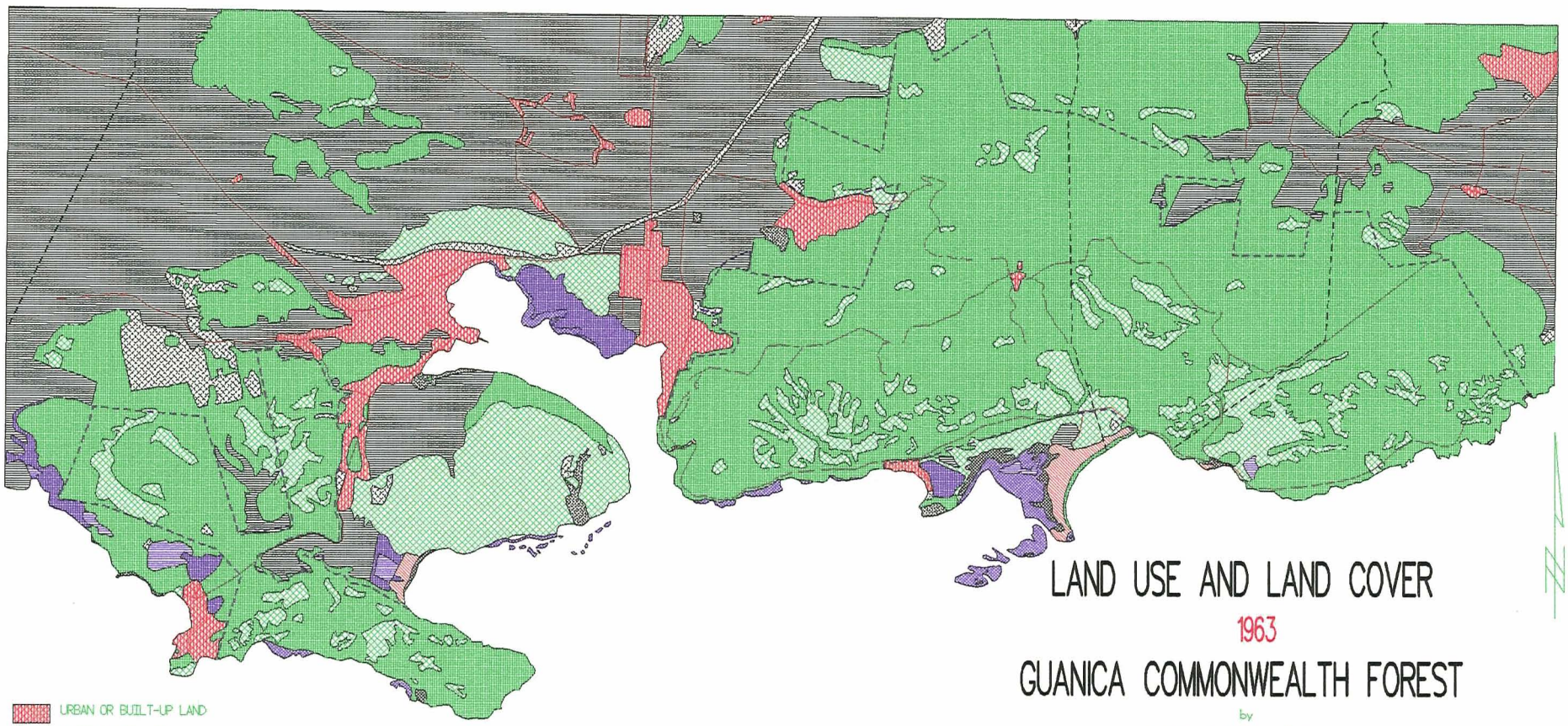

LAND USE AND LAND COVER

1963

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- NATURAL BARREN LAND
- ARTIFICIAL BARREN LAND
- OTHER BARREN LAND

- LAND USE AND LAND COVER
- STREETS, ROADS AND HIGHWAYS
- MUNICIPAL BOUNDARIES
- FOREST BOUNDARIES

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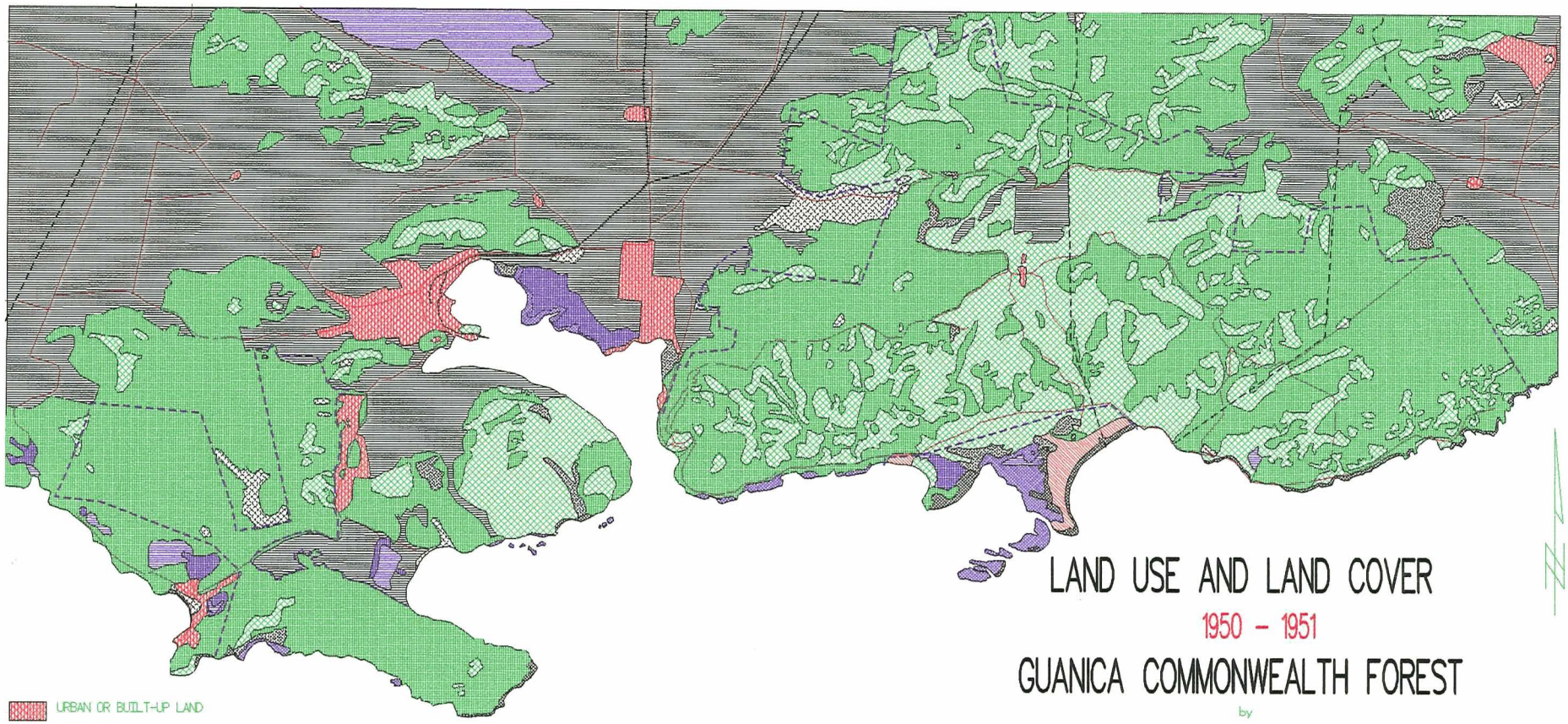

LAND USE AND LAND COVER

1950 - 1951

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- AGRICULTURAL LAND
- WATER
- FOREST LAND (OPEN)
- FOREST LAND (CLOSED)
- PLANTATIONS
- FORESTED WETLAND
- NONFORESTED WETLAND
- NATURAL BARREN LAND
- ARTIFICIAL BARREN LAND
- OTHER BARREN LAND

- LAND USE AND LAND COVER
- STREETS, ROADS AND HIGHWAYS
- MUNICIPAL BOUNDARIES
- RAILROADS
- FOREST BOUNDARIES

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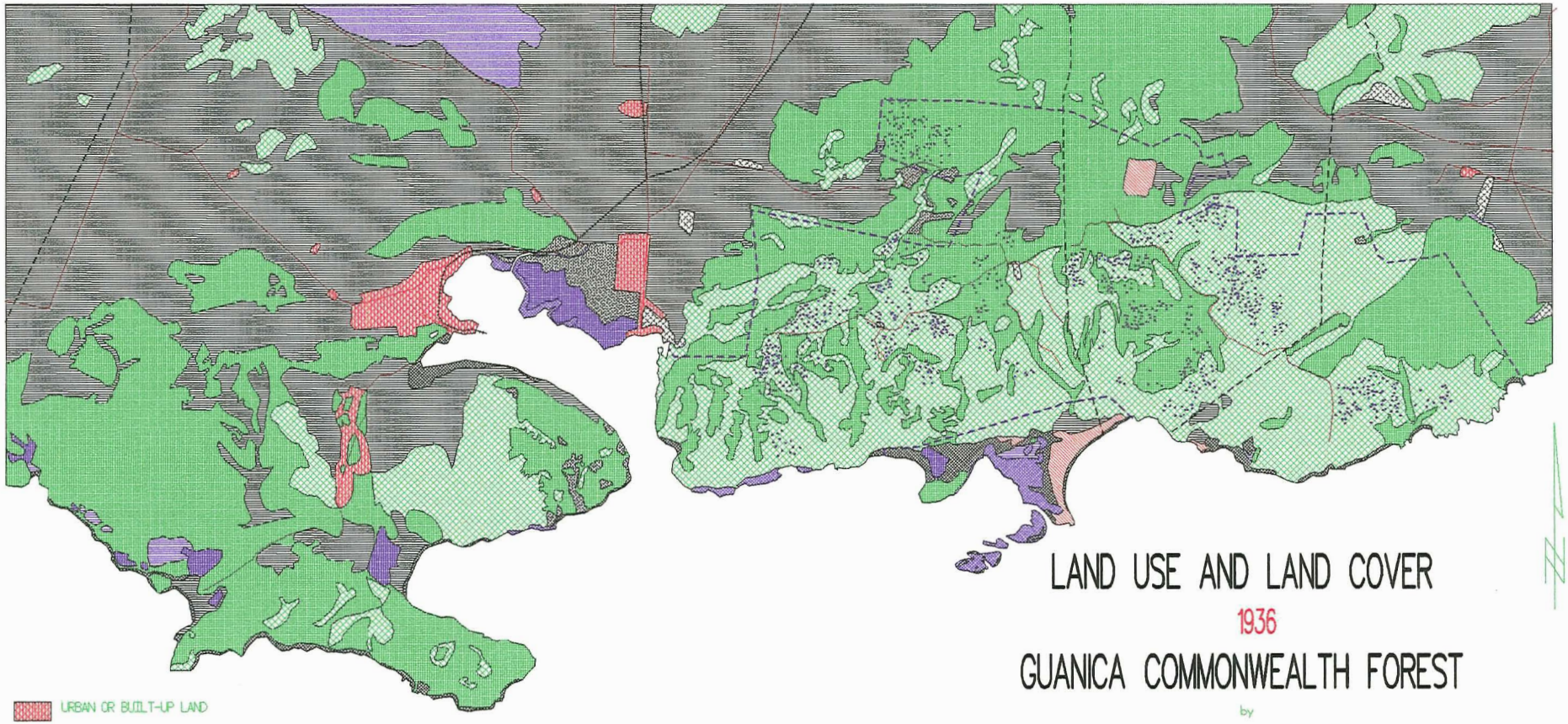

LAND USE AND LAND COVER

1936

GUANICA COMMONWEALTH FOREST

URBAN OR BUILT-UP LAND
AGRICULTURAL LAND
WATER
FOREST LAND (OPEN)
FOREST LAND (CLOSED)
PLANTATIONS
FORESTED WETLAND
NONFORESTED WETLAND
NATURAL BARREN LAND
ARTIFICIAL BARREN LAND
OTHER BARREN LAND

CHARCOAL PIT
LAND USE AND LAND COVER
STREETS, ROADS AND HIGHWAYS
MUNICIPAL BOUNDARIES
RAILROADS
FOREST BOUNDARIES

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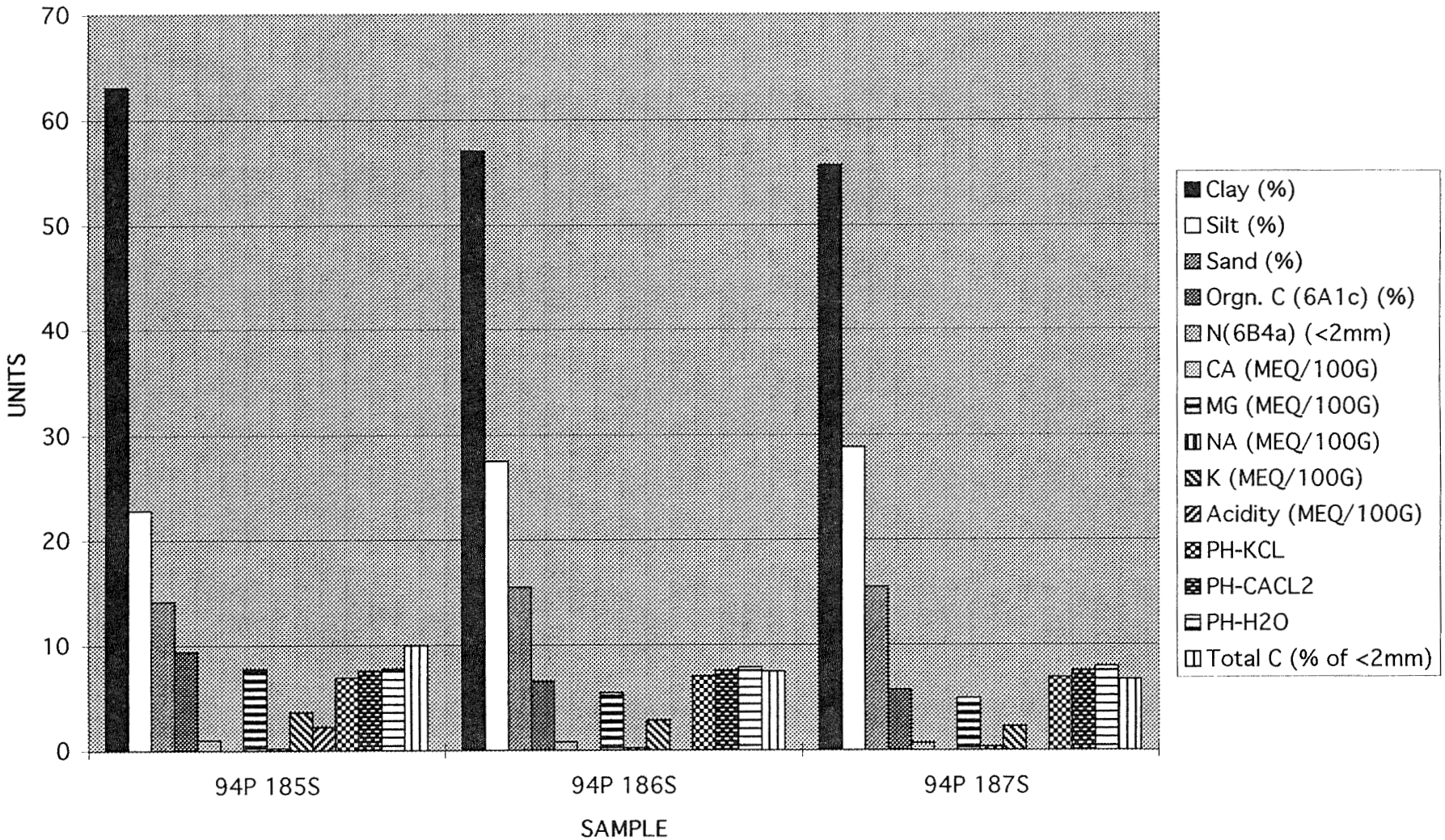
Appendix 2: Bar Graphs of the Soil Samples Analysis

Sample ID	Sample Loc.
S93PR-055-001	Maniel PR-334 Km. 4.18 Guanica
S93PR-055-002	Ballenas S of Plantation Guanica
S93PR-055-003	Ballenas Trail S of Guayacan Guanica
S93PR-055-004	Ballenas 300 ft. N of PR-333 Guanica
S93PR-055-005	Evergreen Comm. Gutierrez Trail Guanica
S93PR-055-006	Granados Trail 500' ENE of Beginning
S93PR-055-007	Surface Sample 100ft. SW of RPT August 92
S93PR-055-008	Lajas Exp. STA. 1/4 Mi. E of LAB
S92PR-000-001	Just S of HWY 333 along Guanica Path Sothware
S92PR-000-002	Lat 17°-58'-15"N Long 66°-51'-57"W
S92PR-000-003	Lat 17°-58'-10"N Long 67°-11'-43"W
S92PR-000-004	Lat 17°-59'-3"N Long 67'-07"W
S92PR-000-005	Guanica Forest
S92PR-000-006	Guanica Forest
S92PR-000-006A	Guanica Forest
S92PR-000-007	Guanica Forest
S92PR-000-007A	Guanica Forest
S02PR-000-008	Guanica Forest
S92PR-000-009	Guanica Forest
S92PR-000-009A	Guanica Forest
S92PR-000-010A	Guanica Forest

S93PR-055-001



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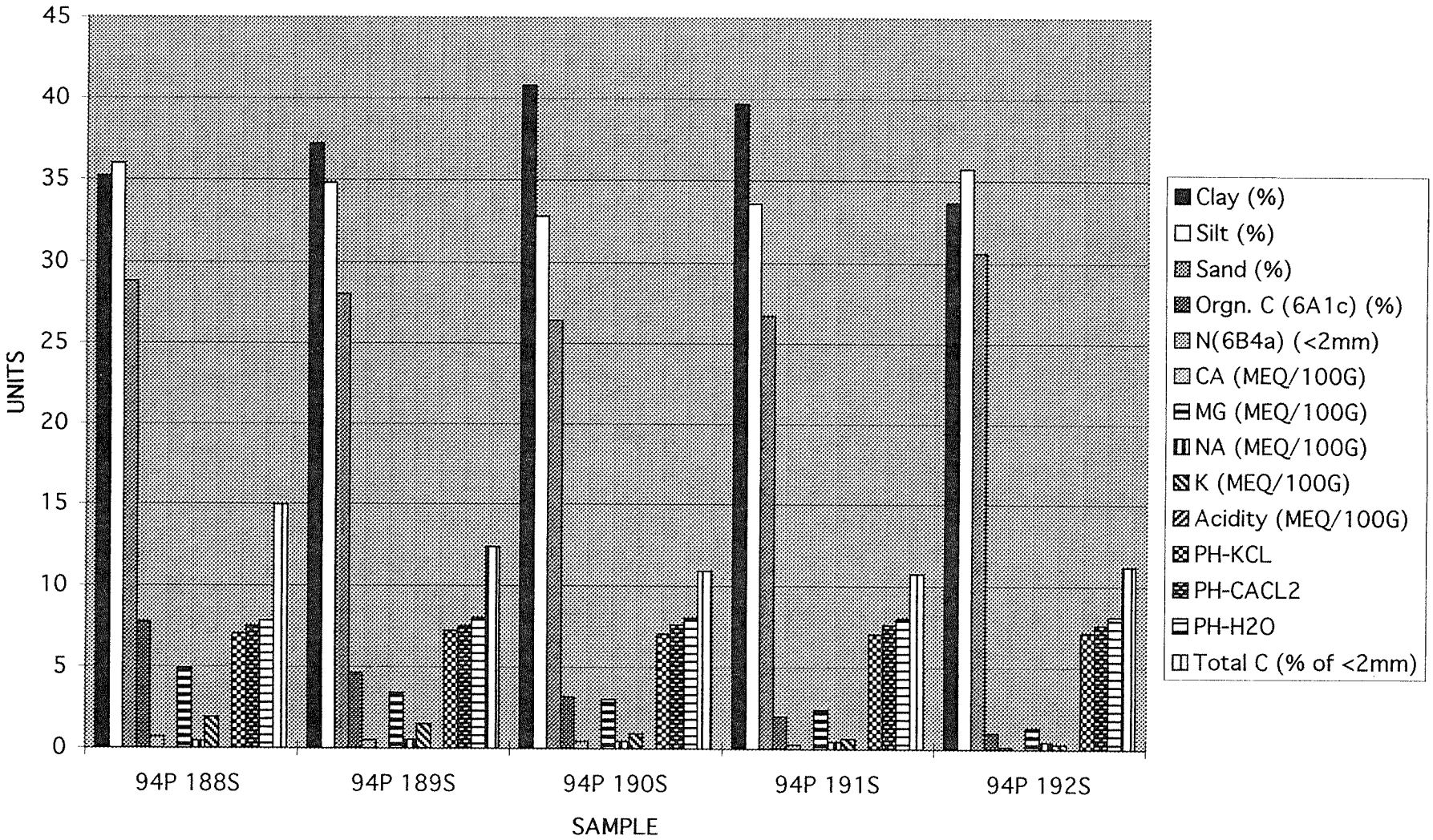

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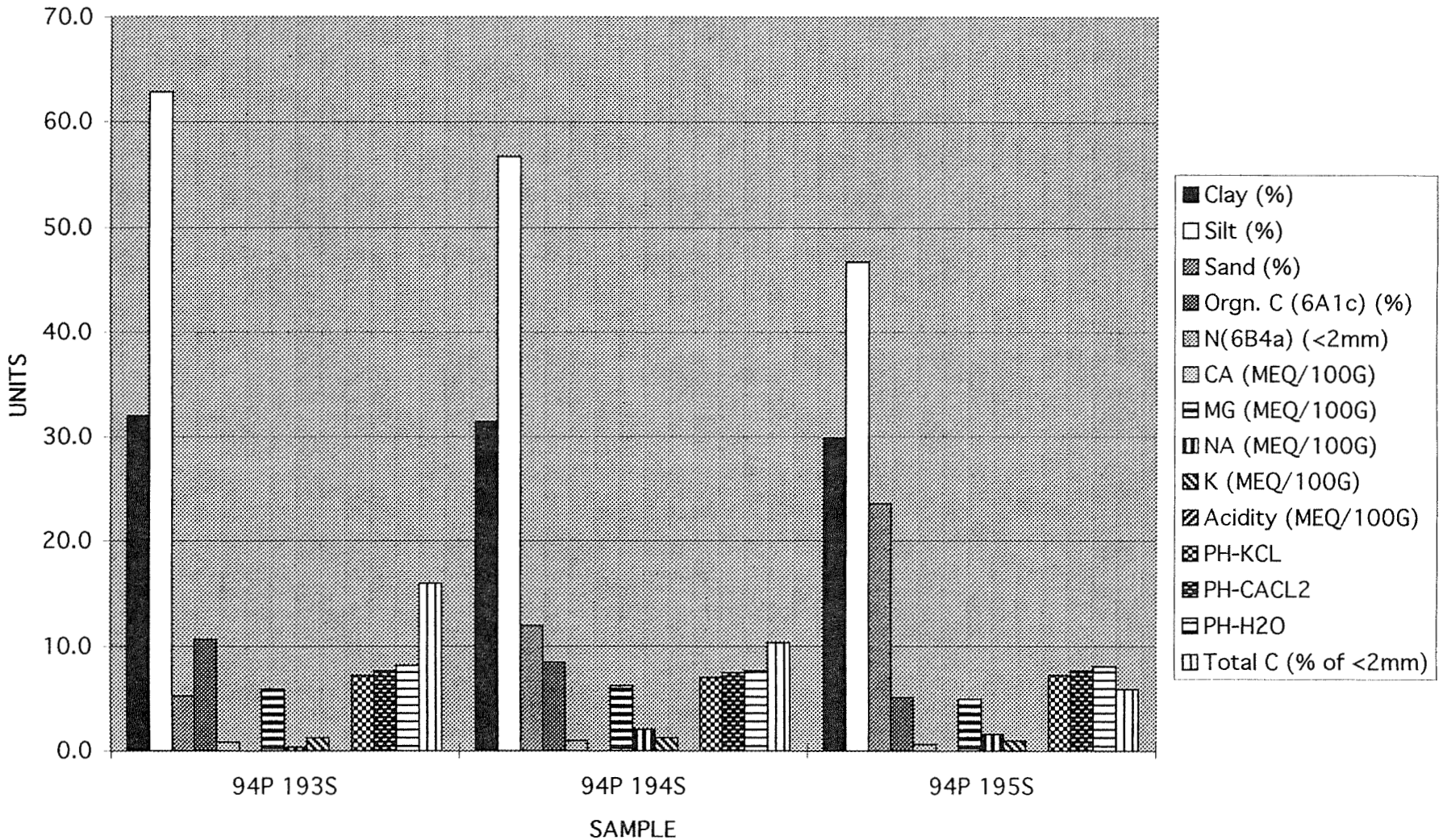

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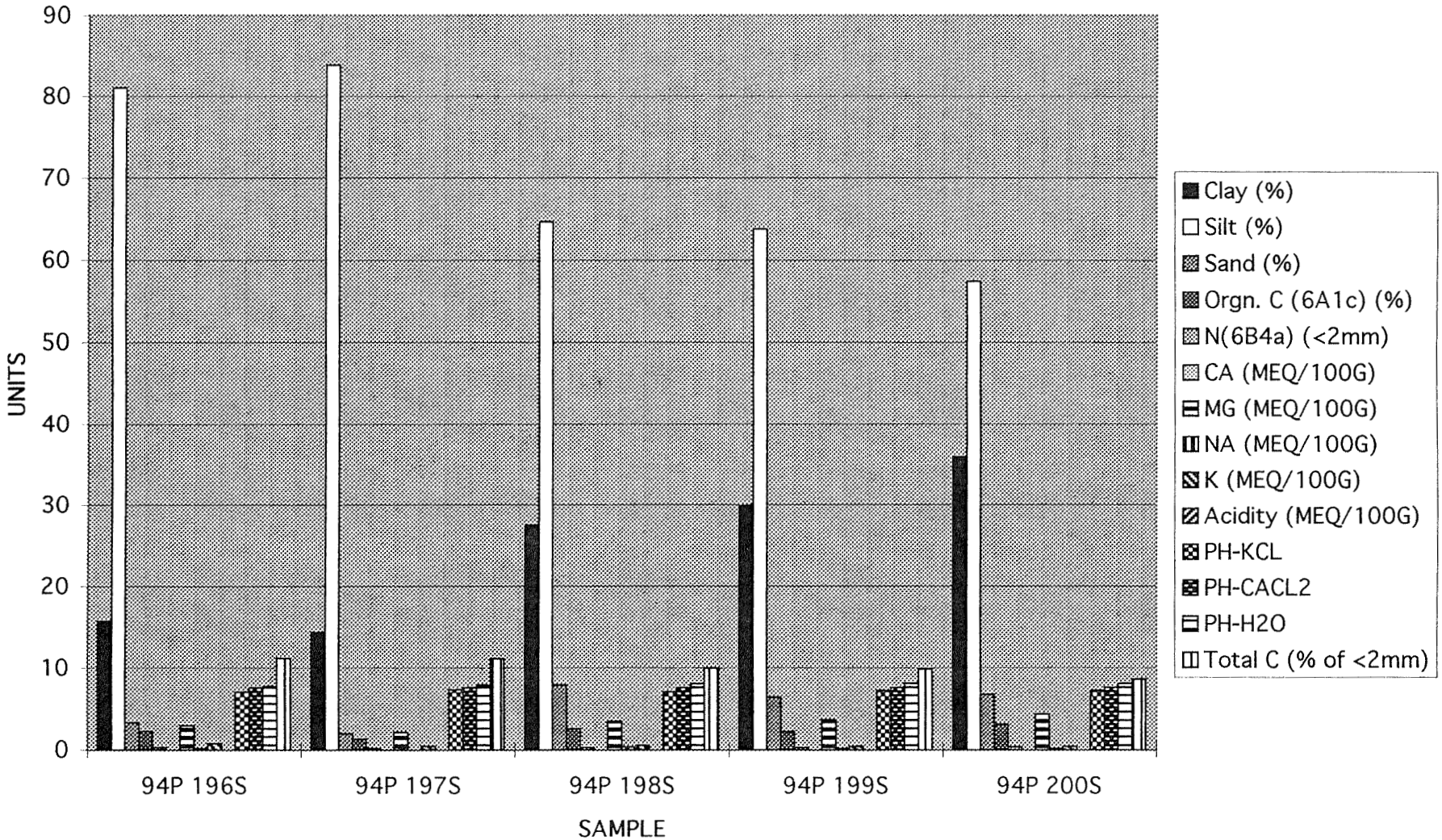

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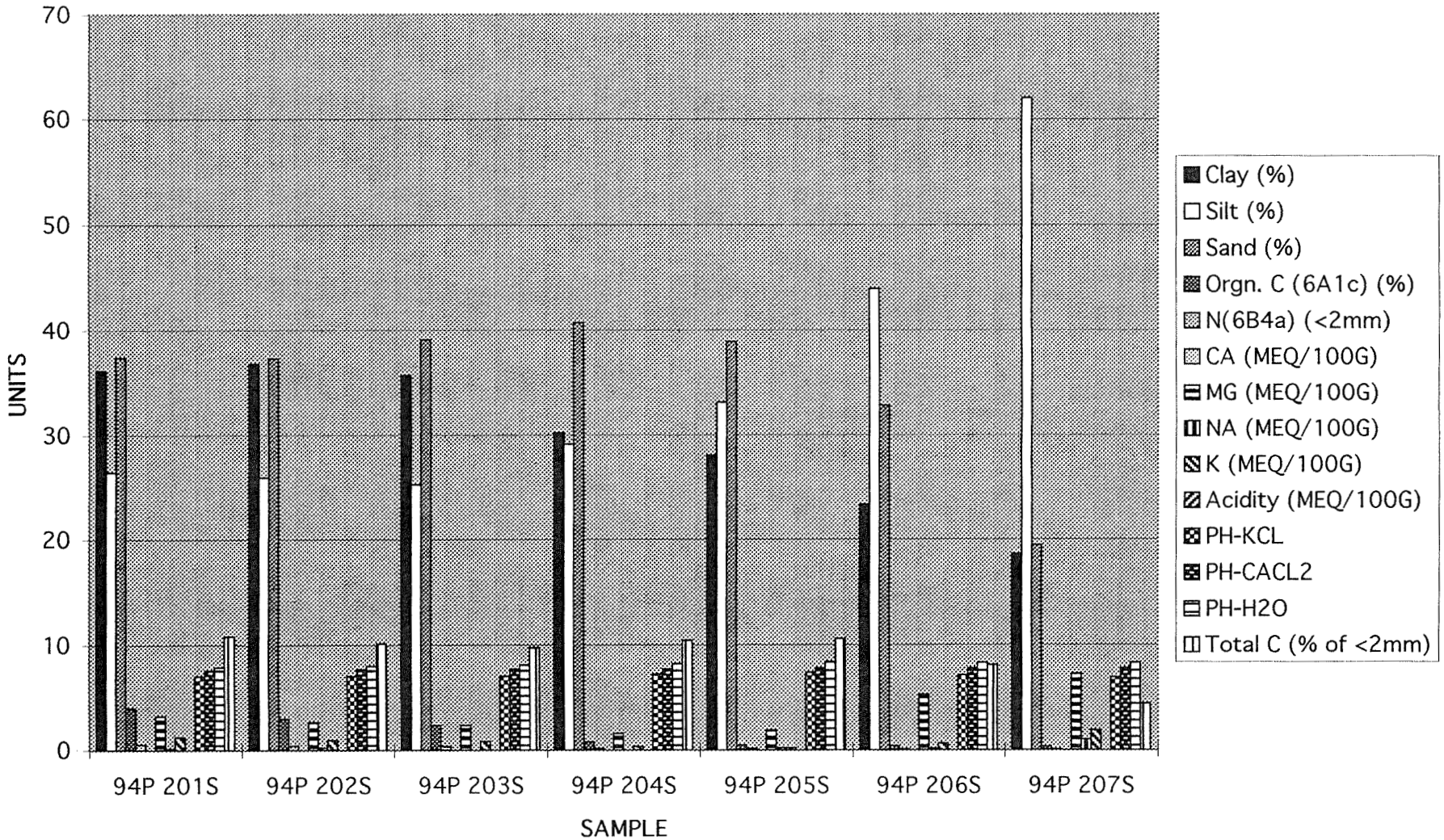

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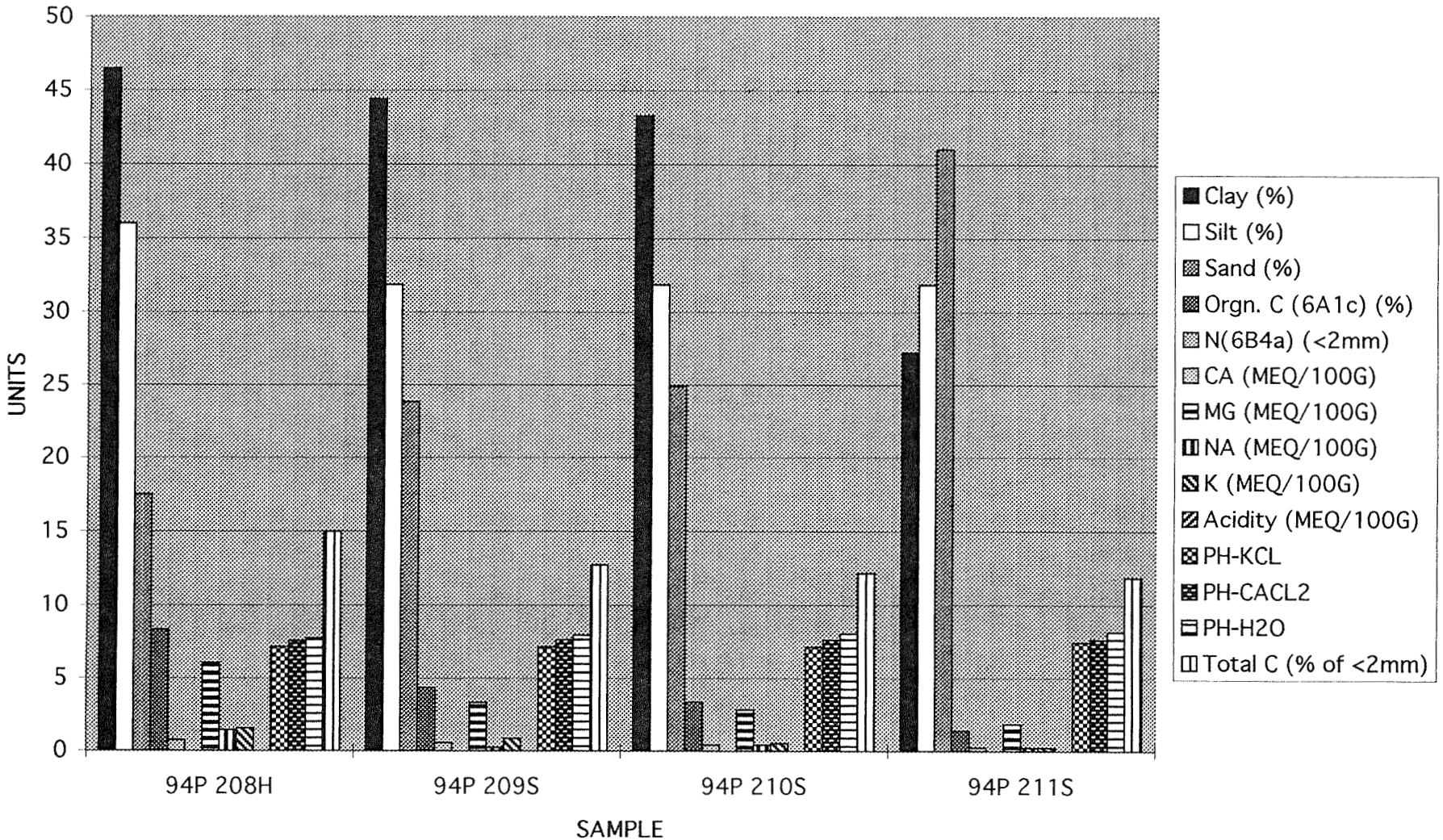

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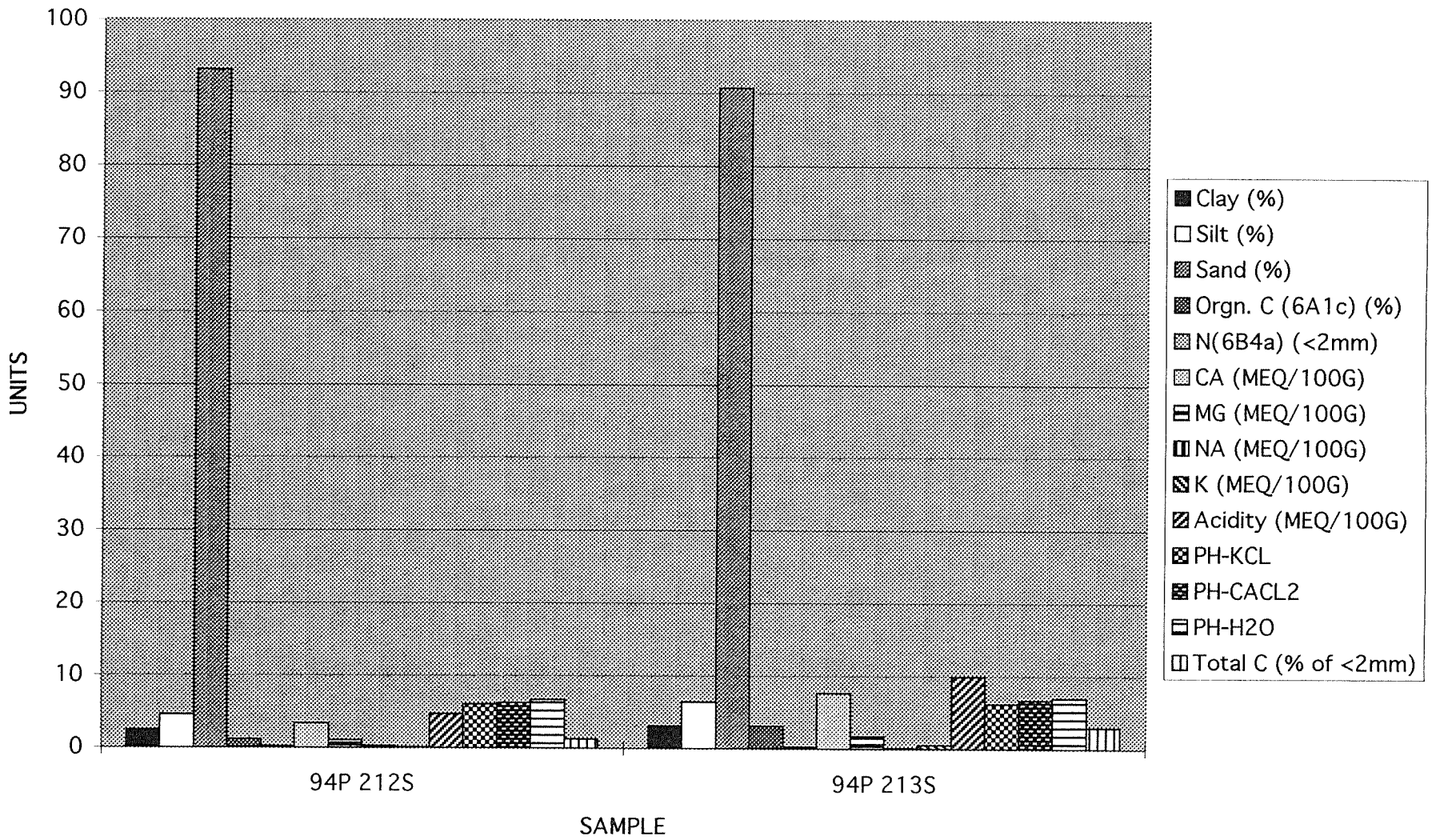

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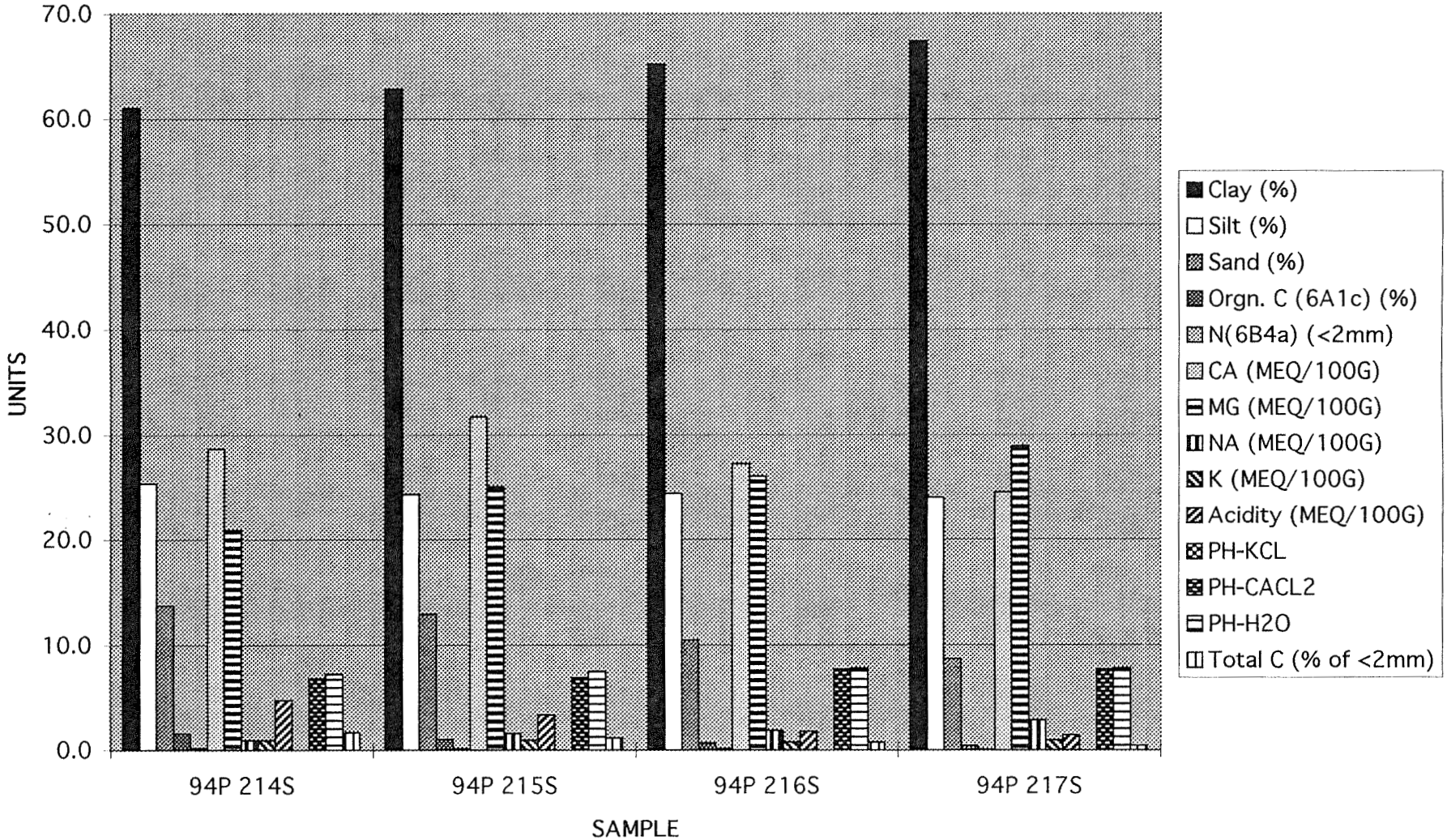

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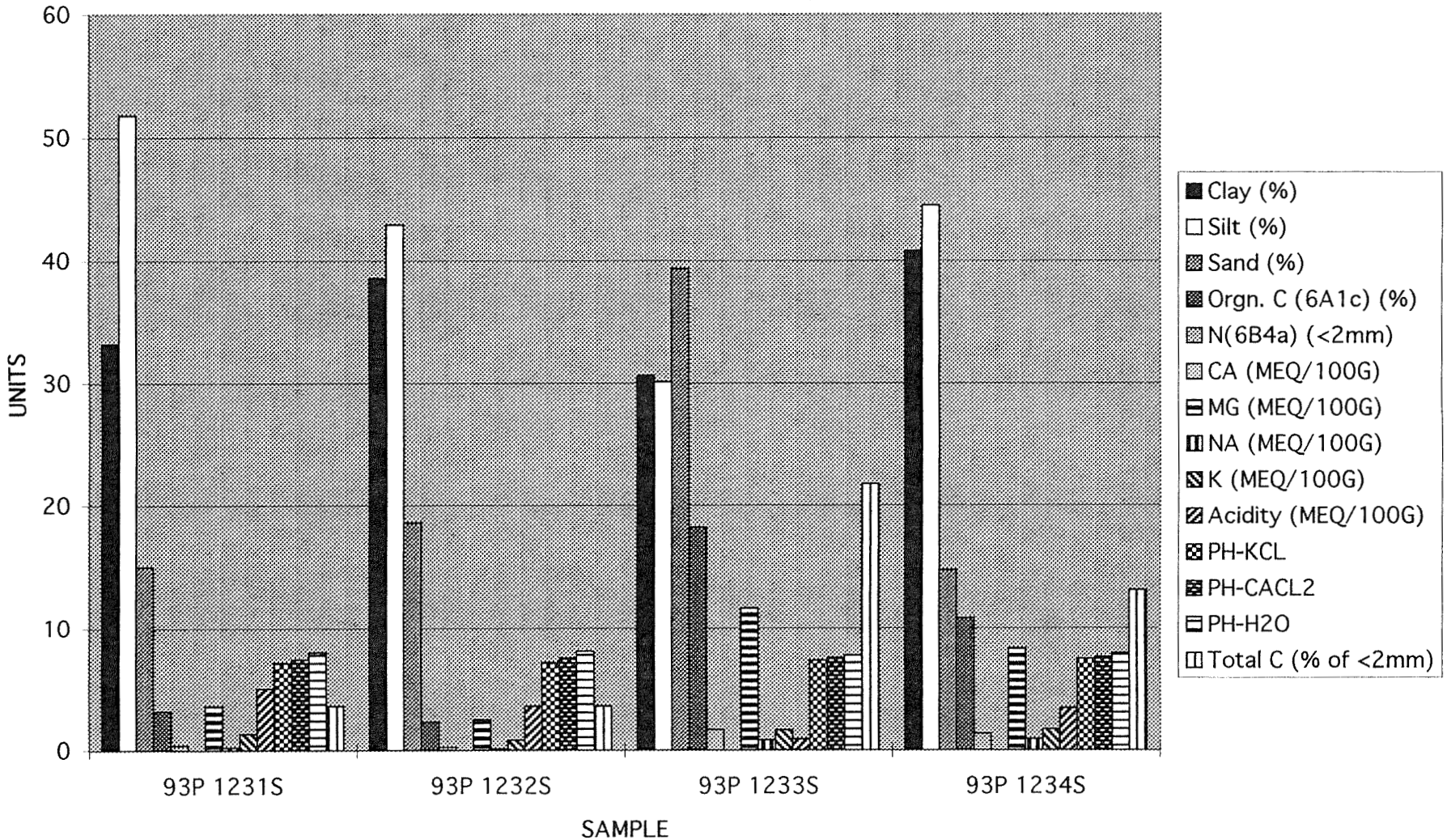

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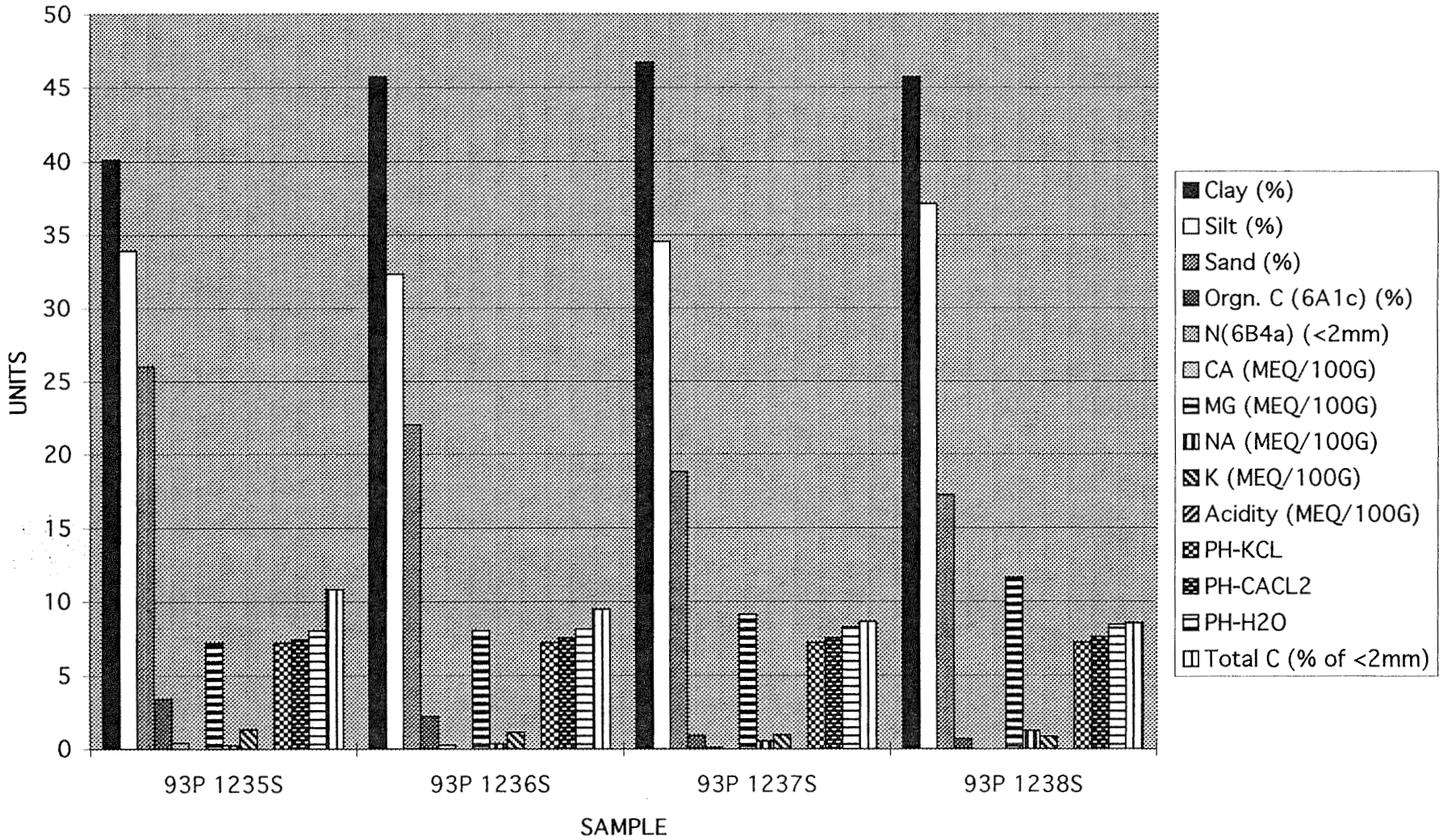

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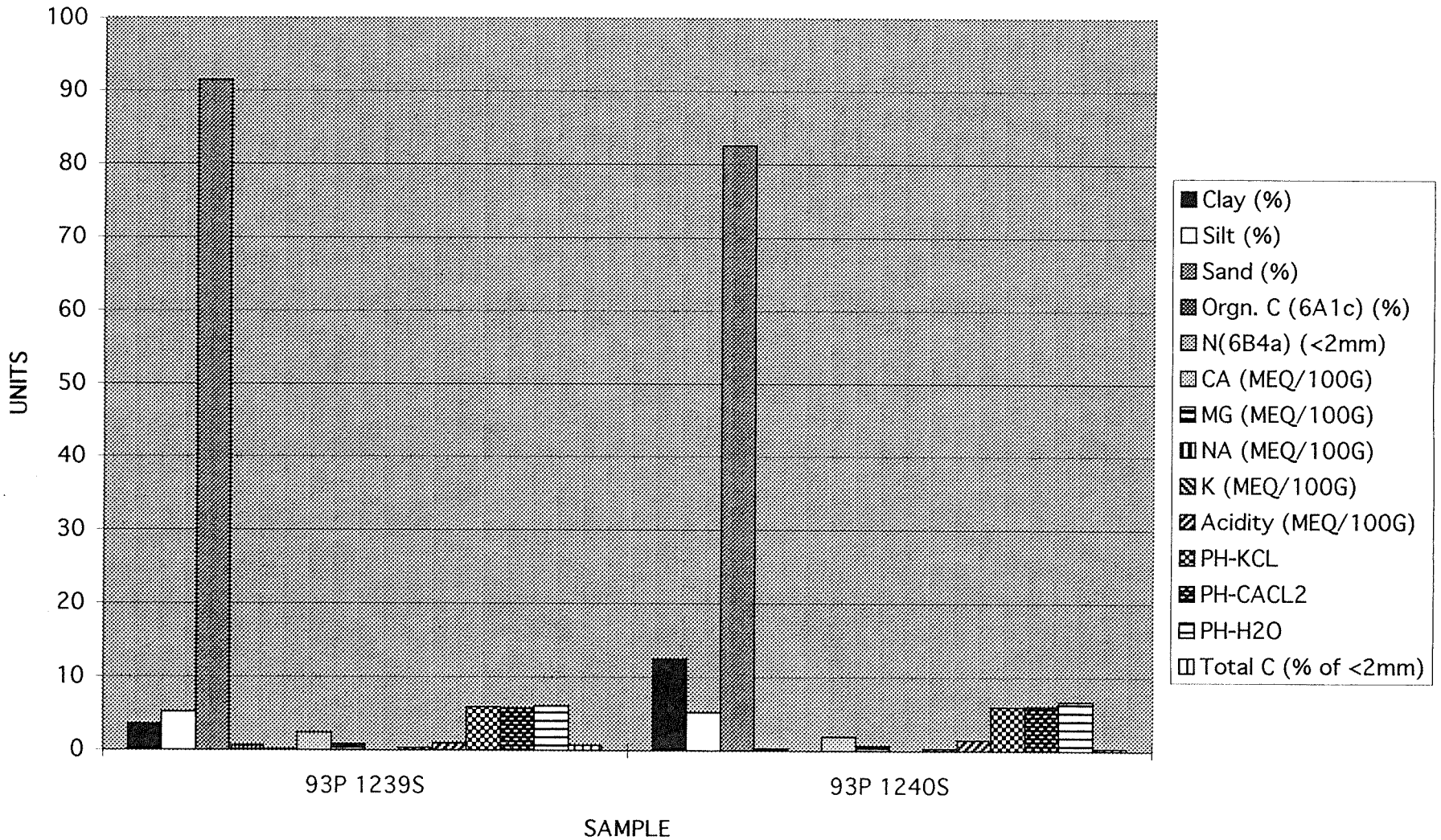

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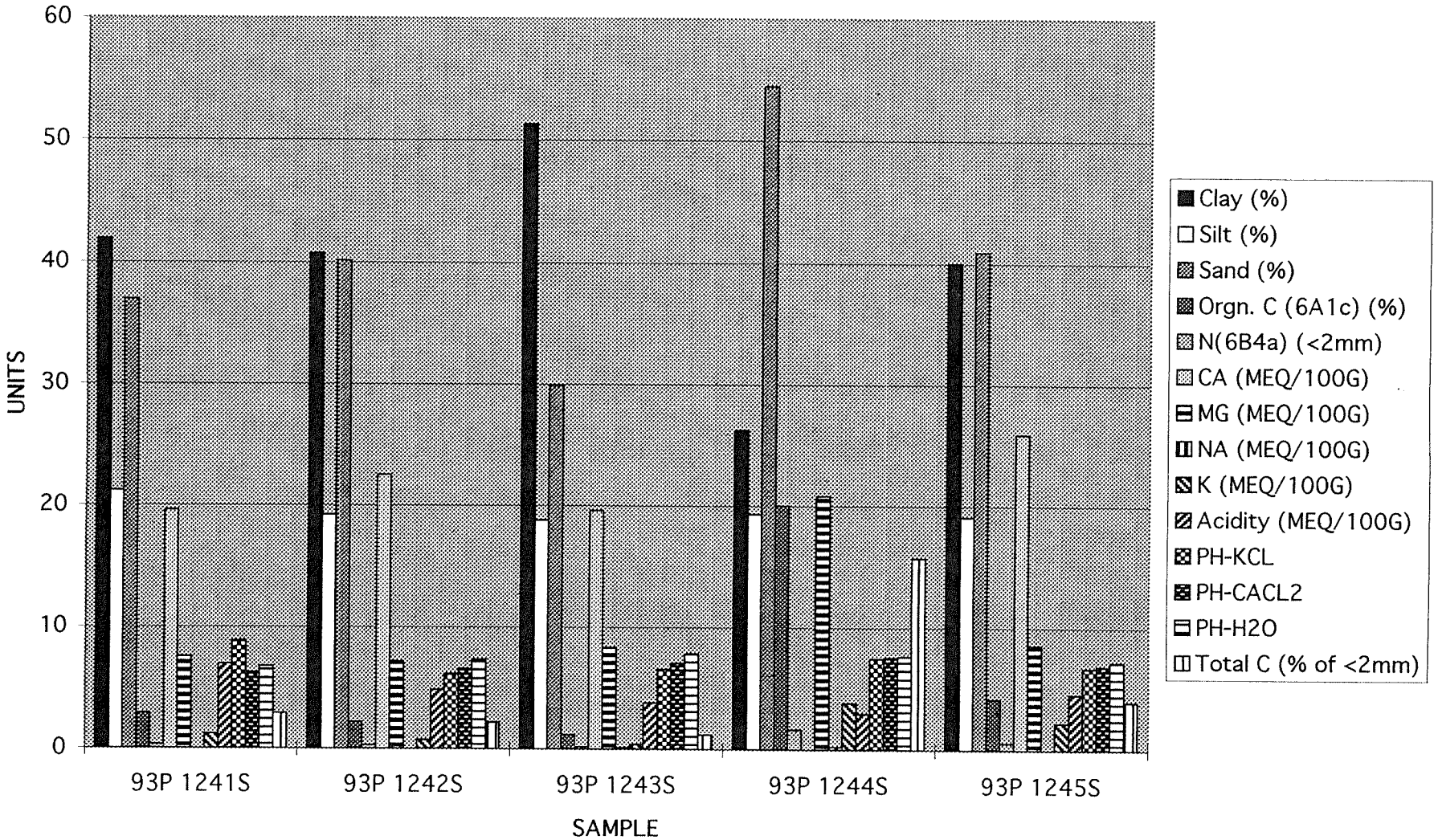

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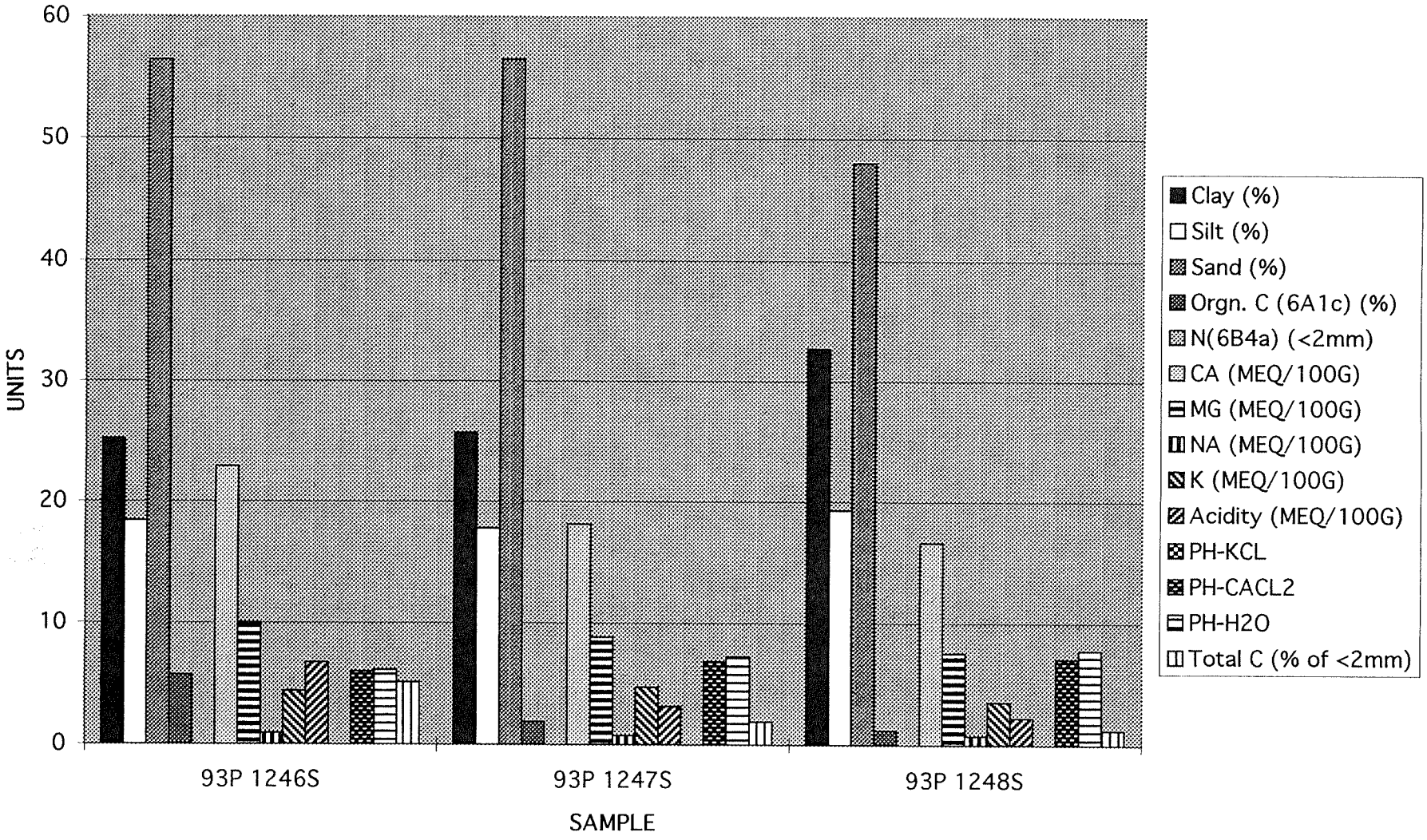

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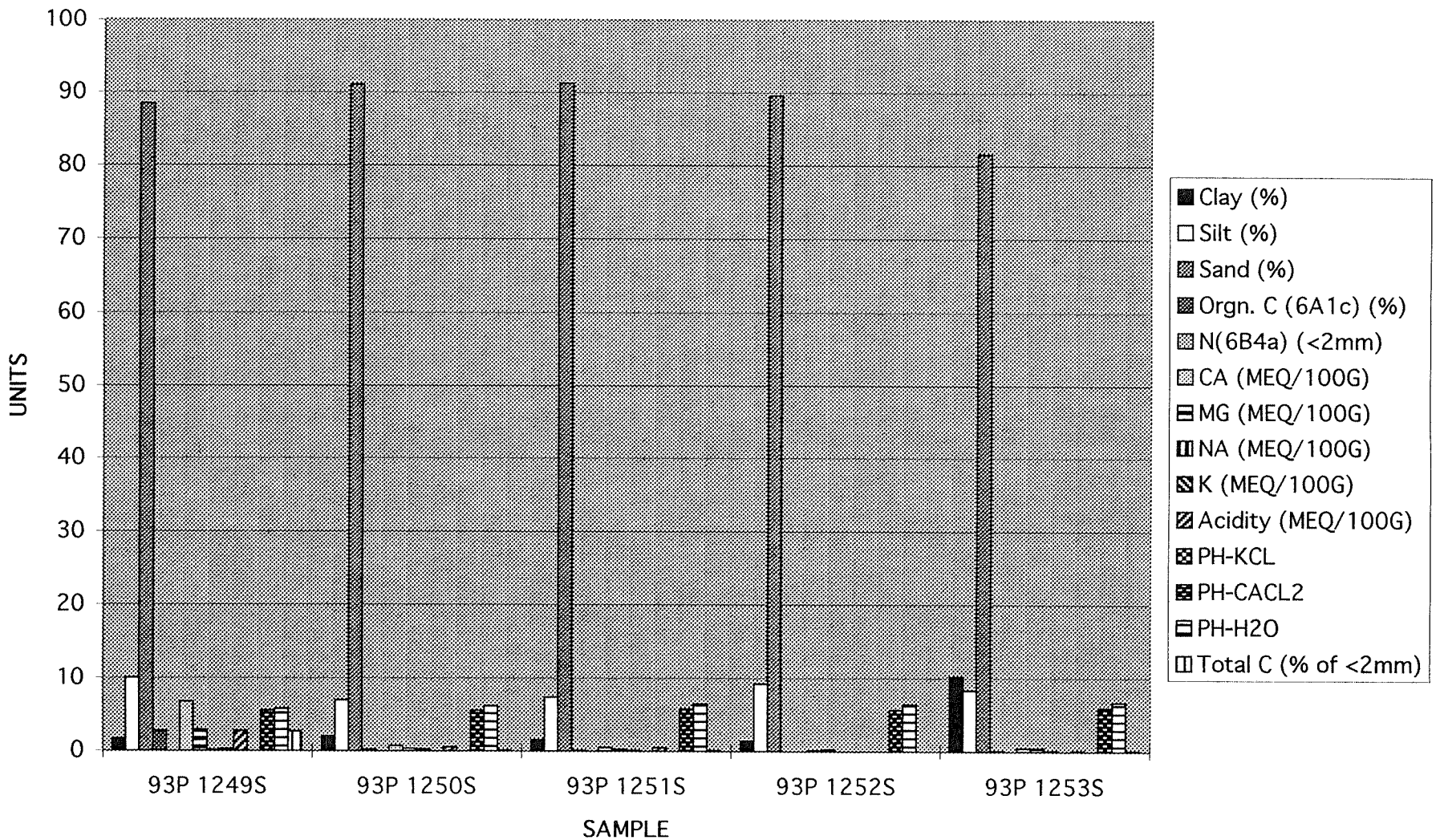

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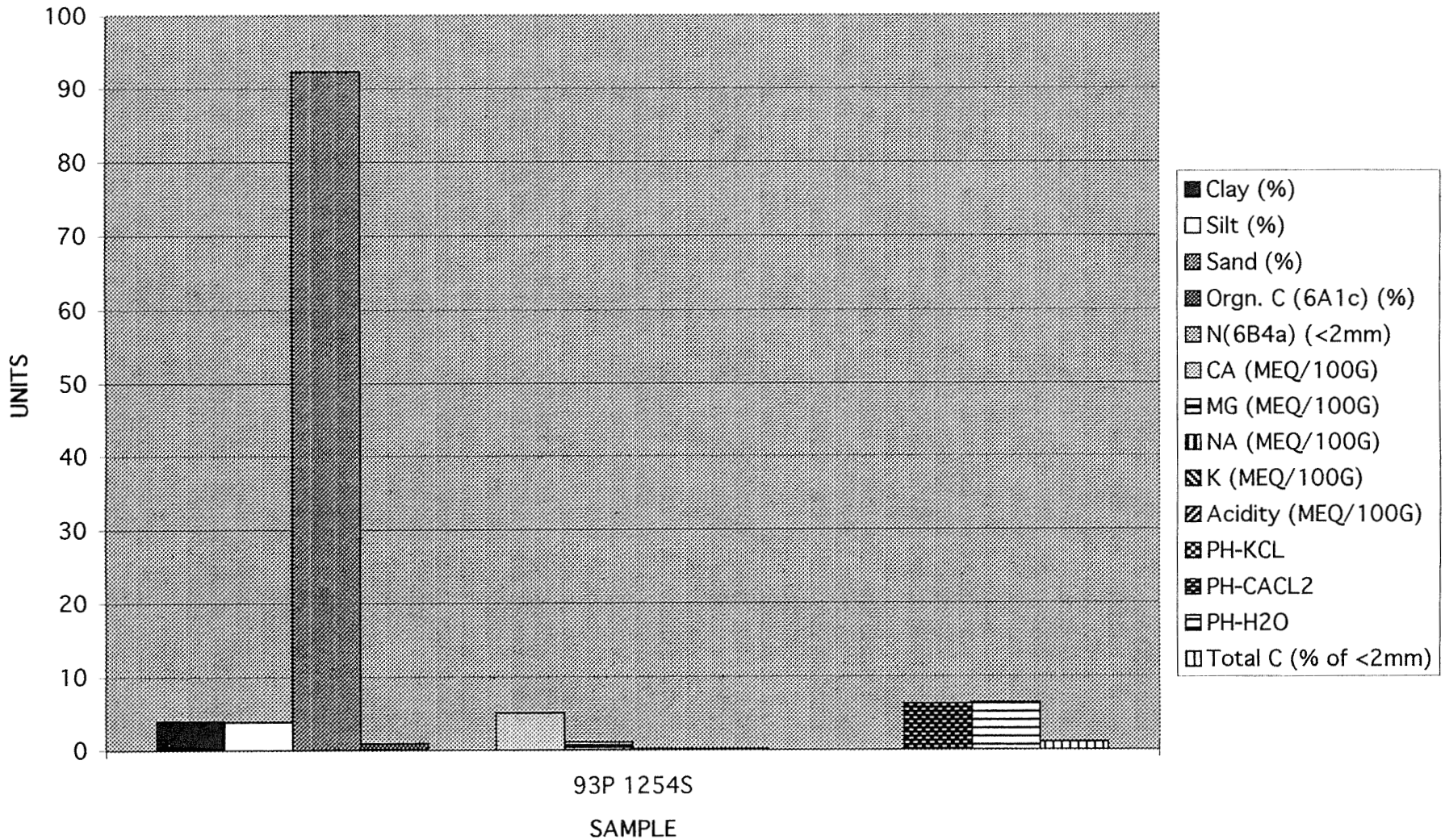

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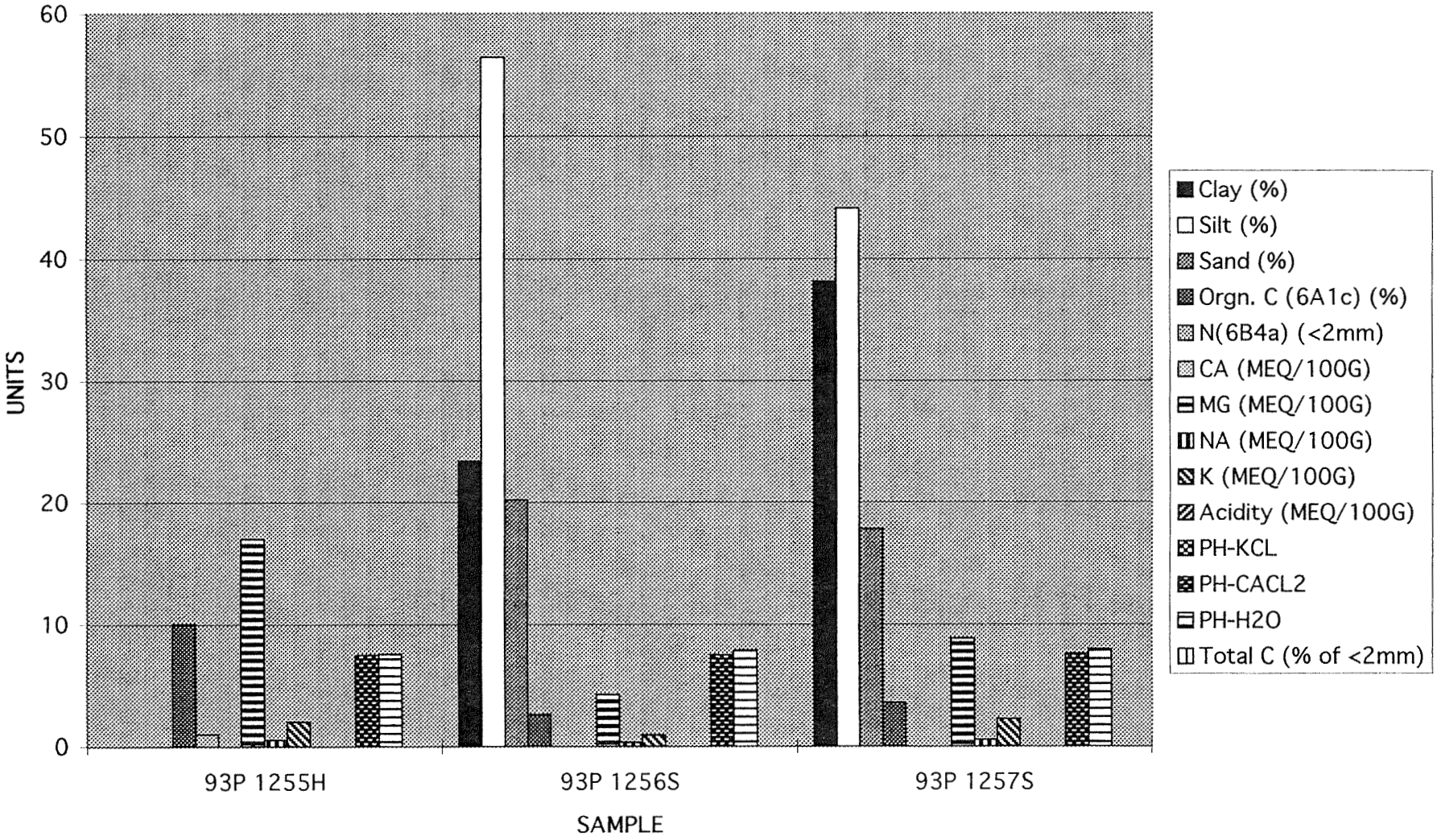
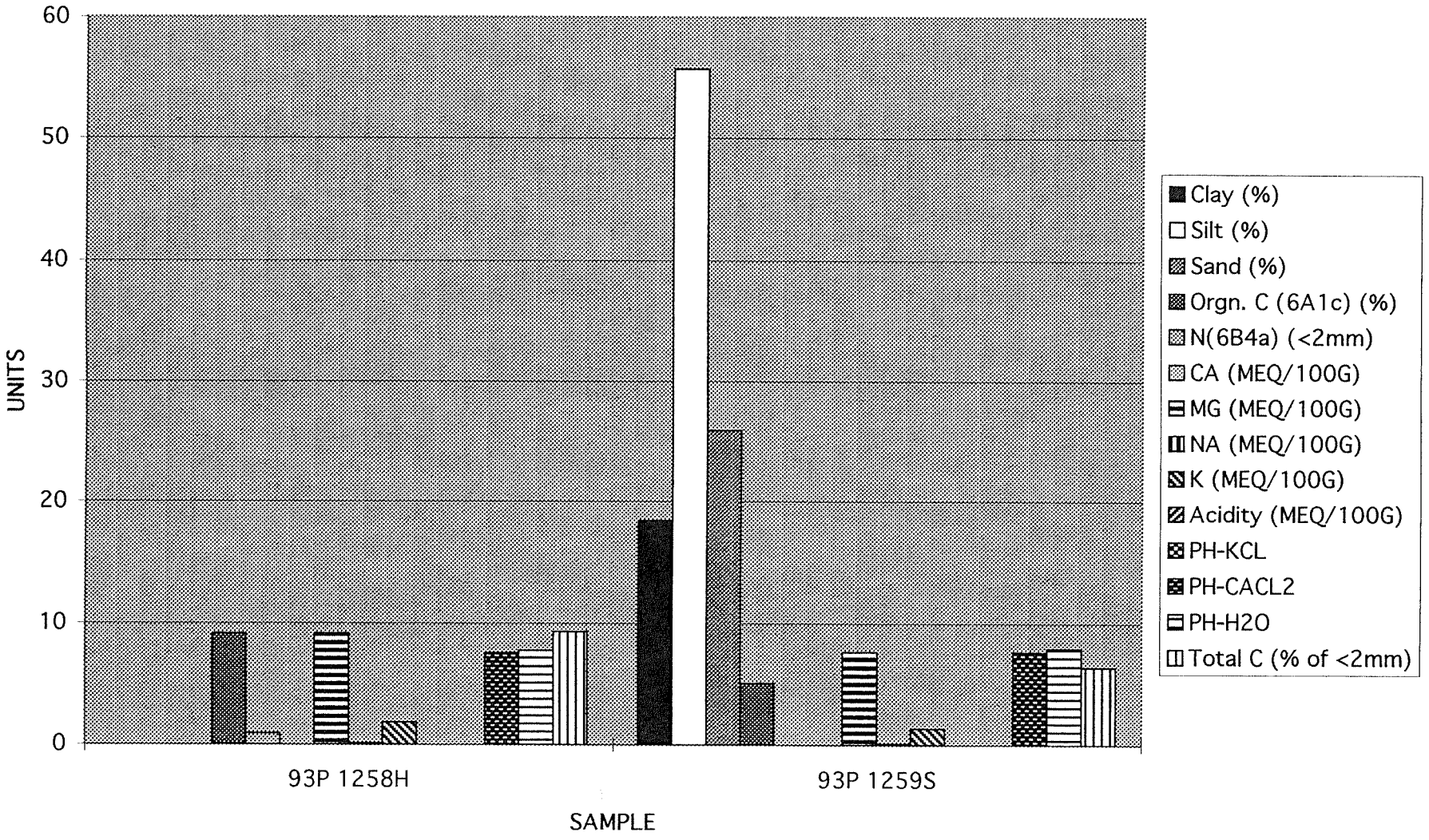
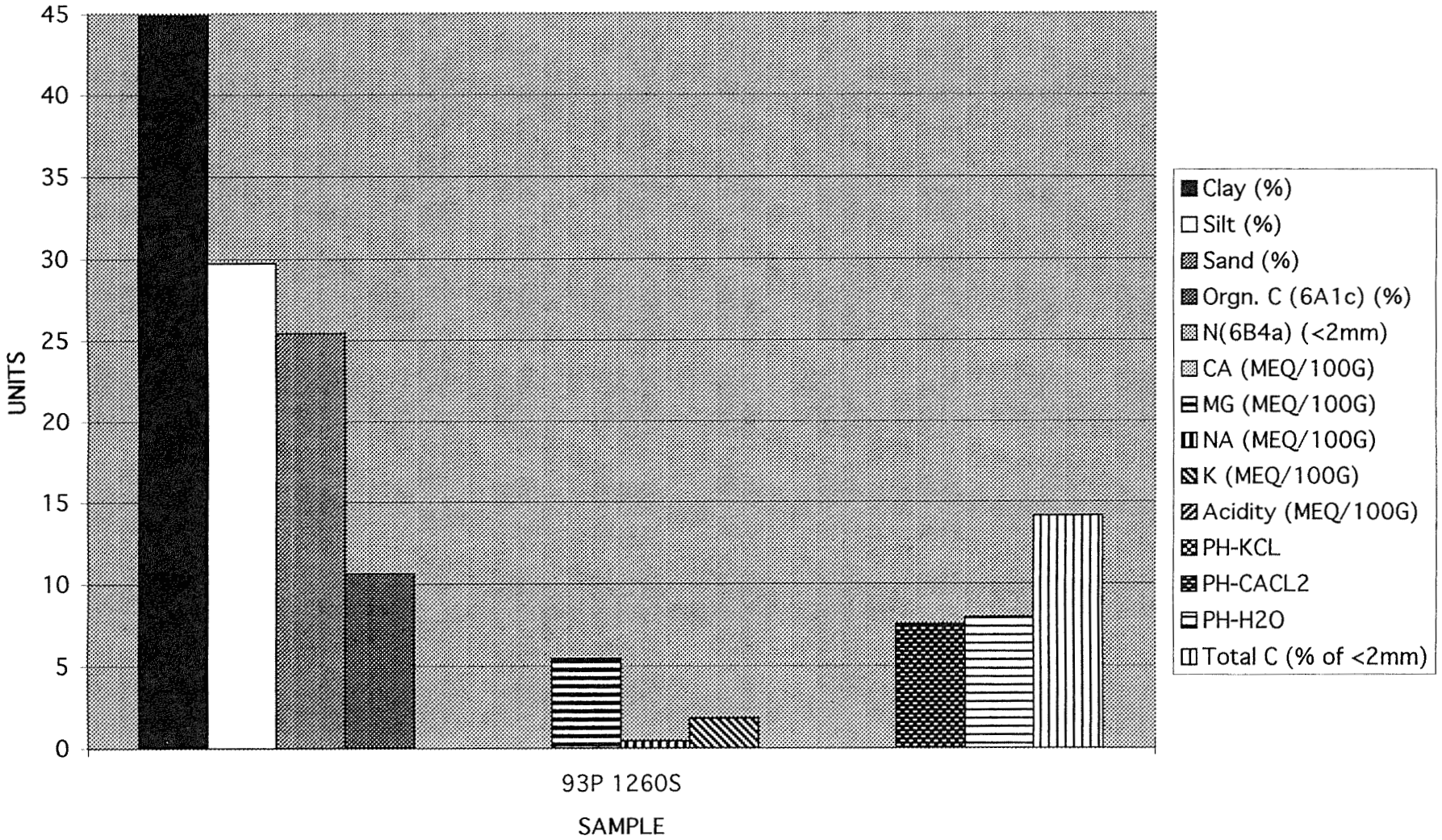


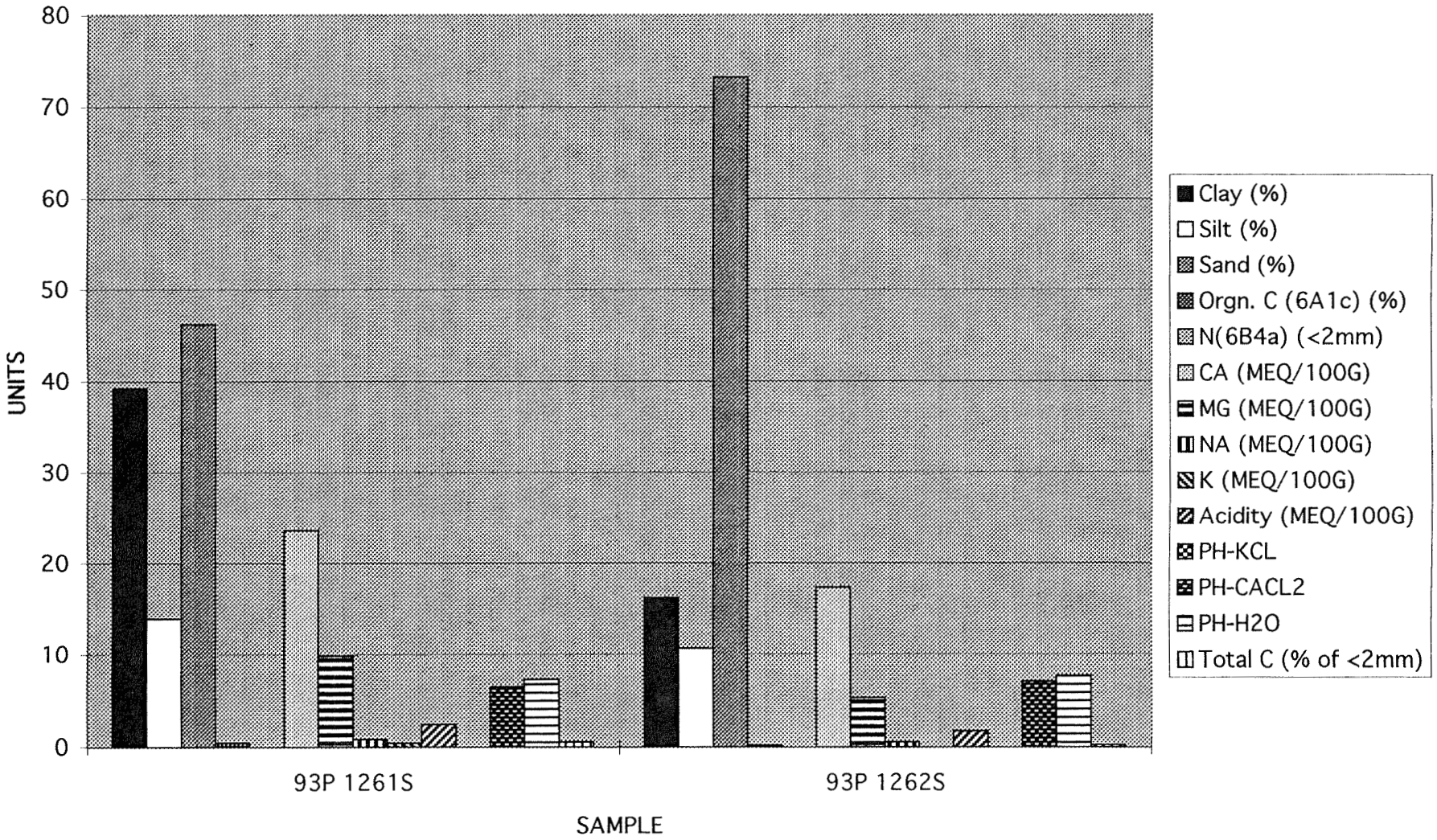
S92PR-000-007A



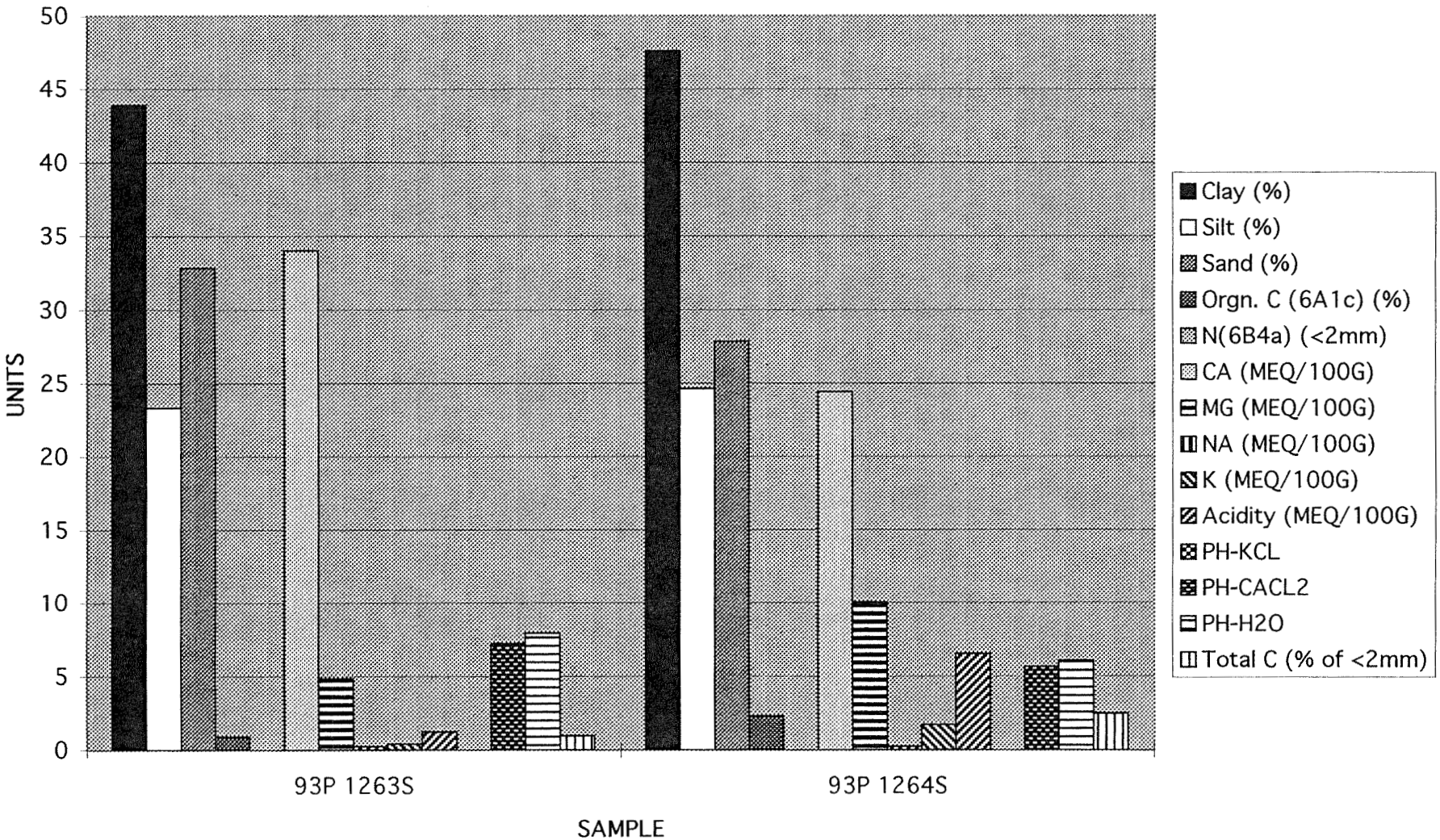
S92PR-000-008



S92PR-000-009



S92PR-000-009A



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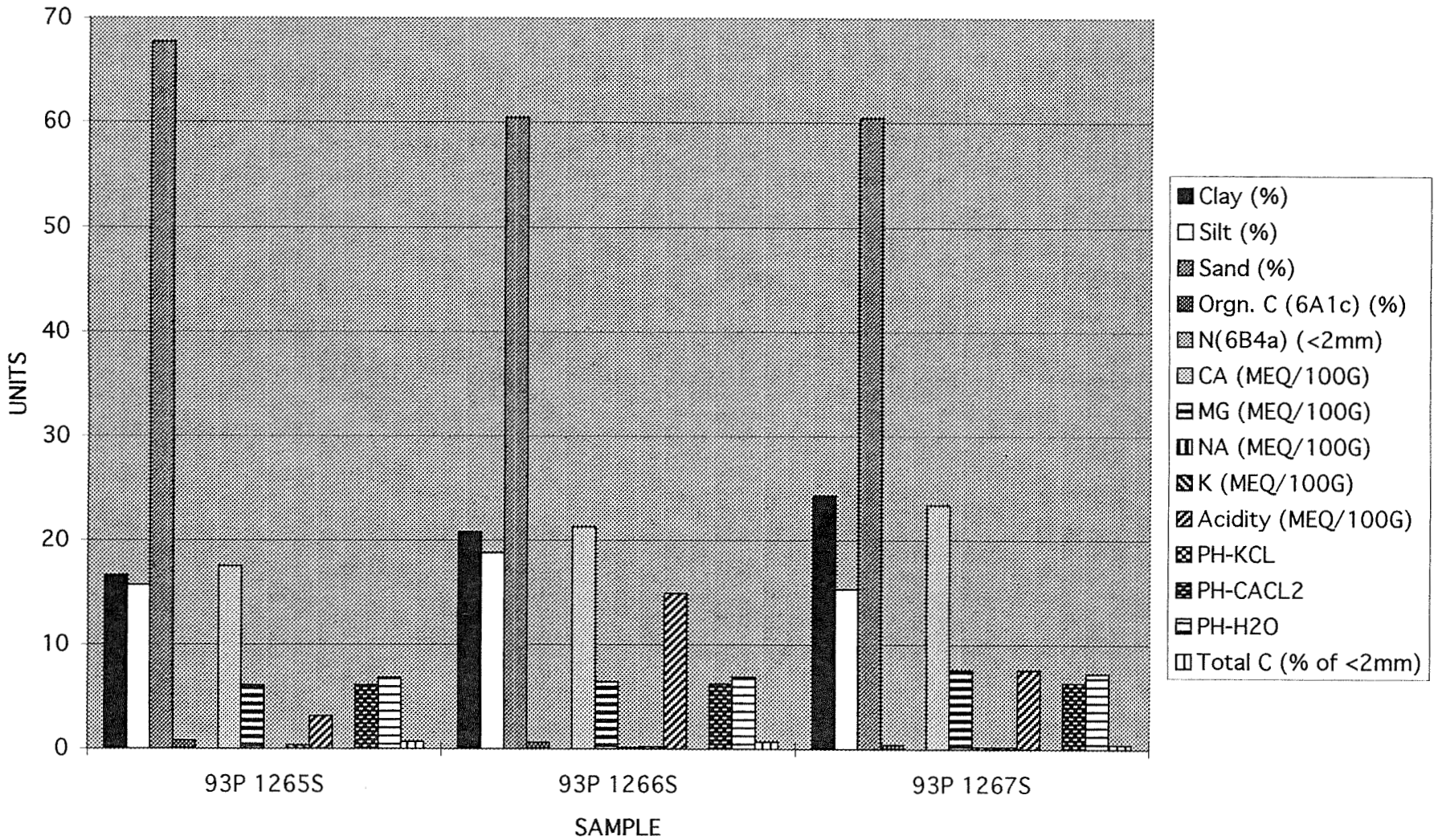
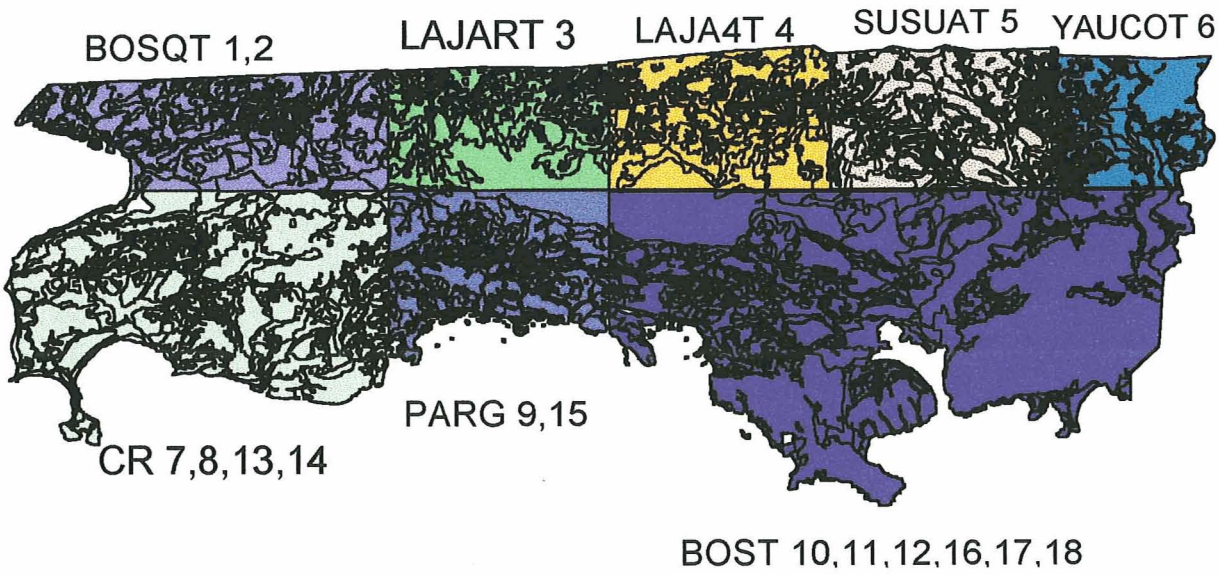


Appendix 3: Digital Soil Survey Maps and Soil Types Index

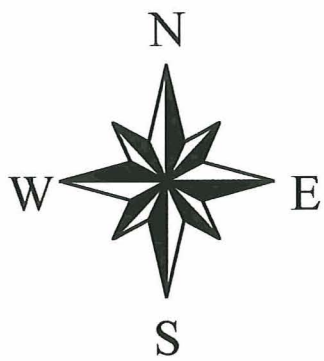
- Lajas Valley Soil Survey
- Ponce Soil Survey
- Humacao Soil Survey
- Lajas Valley Soil Types Index
- Ponce Soil Types Index
- Humacao Soil Types Index

Lajas Valley Soil Survey



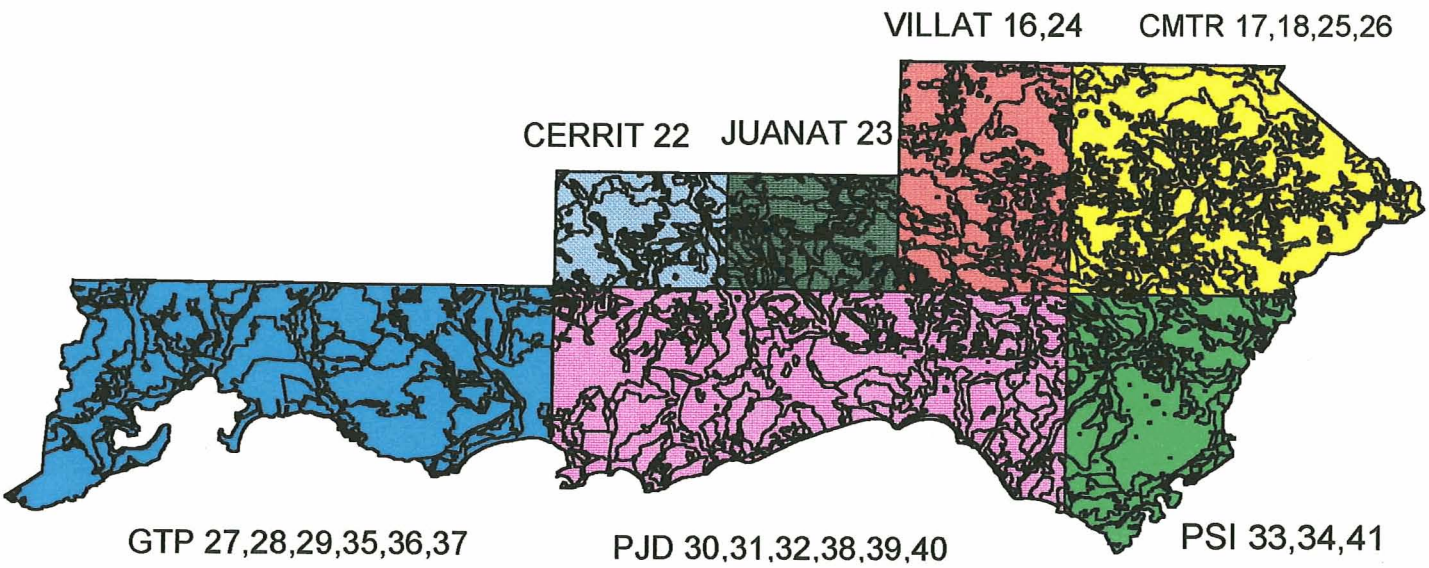
Key

- Guanica Dry Forest
- Susua
- Yauco
- North of Lajas
- Lajas
- Boquerón
- Parguera
- Cabo Rojo



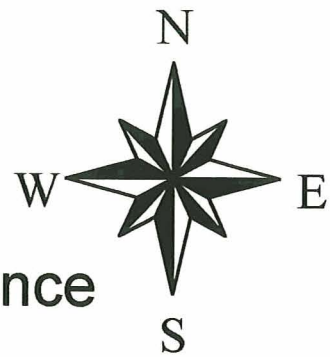
Note : The numbers are the maps identification in the Soil Survey

Ponce Soil Survey



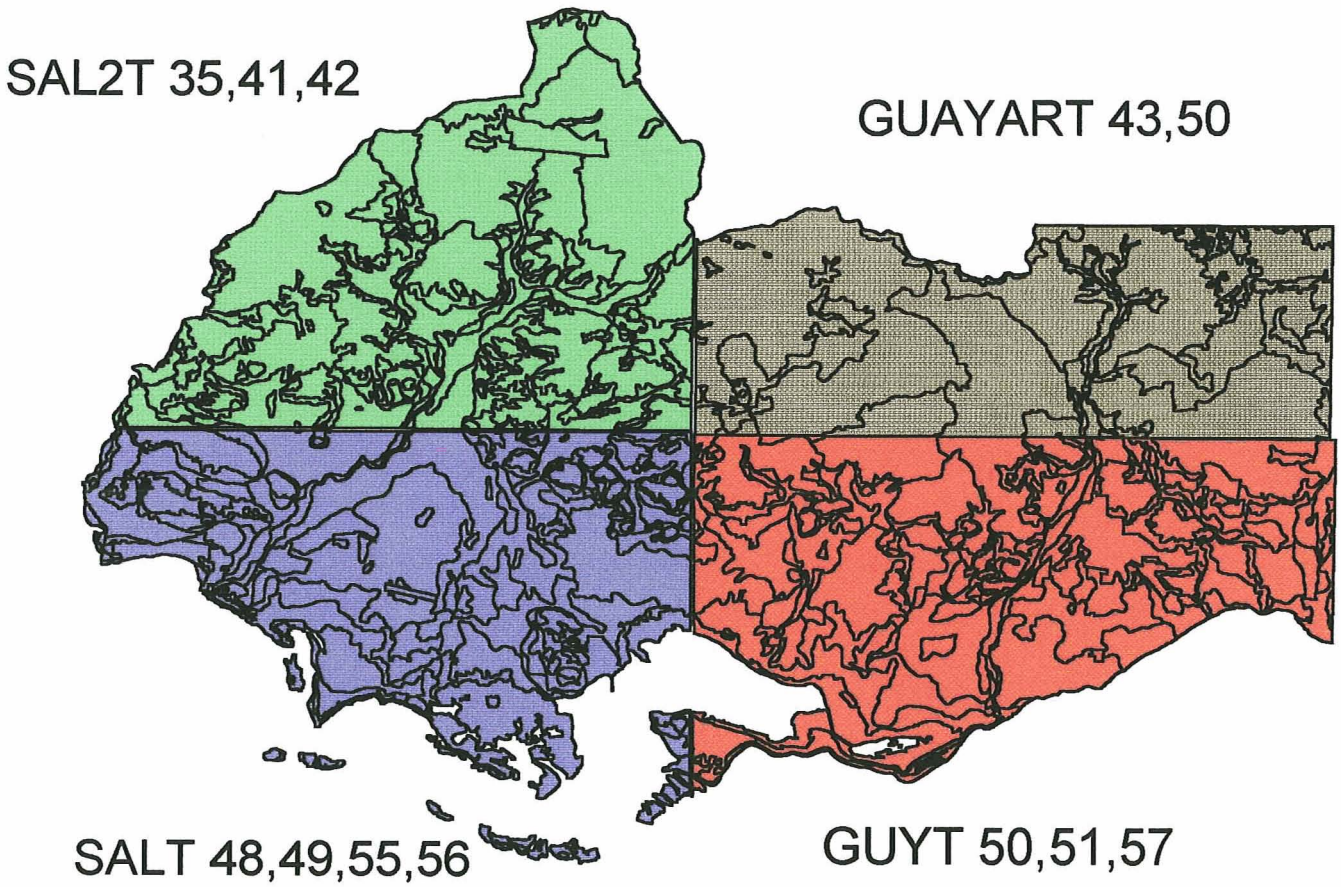
Key

- Cerrillo
- Villalba
- Ponce and Santa Isabel
- Ponce and Juana Diáz
- Juana Diáz
- Guayanilla,Tallaboa and Ponce
- Coamo



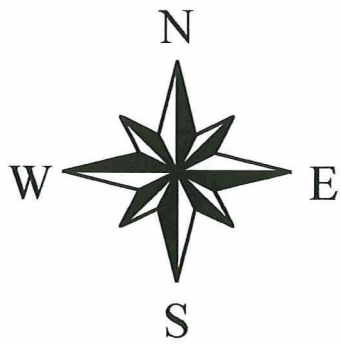
Note : The numbers are the maps identification in the Soil Survey

Humacao Soil Survey



Key

- North of Salinas
- Salinas
- Guayama
- North of Gayama



Note : The numbers are the maps identification in the Soil Survey

LAJAS VALLEY SOIL SURVEY									
Type of Soil	SHADING #	CR	PARG	SUSUA	BOS3	BOQ	LAJAR	YAUCO	LAJA4
DeD	19	YES	YES	YES	YES	YES	YES	YES	YES
DeF	30	YES	YES	YES	YES	YES	YES	YES	YES
JaC	43	YES	YES	YES	YES	YES	YES	YES	YES
SgF	8	YES	YES	YES	NO	YES	YES	NO	YES
JaB	42	YES	YES	YES	YES	YES	YES	YES	YES
Sa	32	YES	NO	YES	YES	YES	YES	YES	YES
DeC	18	YES	YES	YES	YES	YES	YES	YES	YES
Lr	12	YES	YES	YES	YES	YES	YES	YES	YES
JaD2	44	YES	YES	YES	YES	YES	YES	NO	YES
SgD	7	YES	YES	YES	YES	YES	YES	YES	YES
Co	10	YES	YES	NO	NO	YES	NO	NO	NO
JcC	48	YES	YES	YES	YES	YES	YES	YES	YES
FvA	34	YES	YES	YES	YES	YES	YES	YES	YES
SsD2	50	YES	NO	NO	NO	YES	NO	NO	NO
Ca	94	YES	YES	YES	YES	YES	YES	YES	YES
AcD	59	YES	NO	NO	YES	YES	NO	NO	NO
FrA	20	YES	YES	YES	YES	YES	YES	YES	YES
AcE	66	YES	NO	NO	YES	YES	NO	NO	NO
WATER	4	YES	YES	YES	Pump	YES	YES	YES	NO
Tc	14	YES	YES	NO	NO	YES	NO	NO	NO
FvA	34	YES	YES	YES	YES	YES	YES	YES	YES
Ts	16	YES	YES	NO	NO	YES	NO	NO	NO
PcB	24	YES	NO	NO	NO	YES	YES	NO	NO
AmC2	91	YES	YES	NO	NO	YES	NO	NO	NO
PzC	99	YES	YES	YES	YES	YES	YES	YES	YES
SoA	11	YES	NO	NO	NO	YES	NO	NO	NO
Va	27	YES	NO	YES	YES	YES	NO	YES	NO
Gf	33	YES	NO	NO	NO	YES	NO	NO	NO
Gc	6	YES	NO	NO	YES	YES	YES	NO	YES
Ag	90	YES	YES	NO	YES	YES	YES	NO	YES
FrB	31	YES	YES	YES	YES	YES	YES	YES	YES
JaC2	47	YES	YES	YES	YES	NO	YES	YES	YES
JcB	46	YES	YES	YES	YES	NO	YES	YES	YES
PzB	98	NO	YES	YES	YES	NO	YES	YES	NO
PzD	100	YES	YES	NO	YES	NO	NO	YES	NO
PaC2	55	NO	NO	NO	NO	YES	YES	NO	NO
MaD2	87	NO	NO	NO	NO	YES	YES	NO	NO
FvB	2	NO	YES	YES	YES	YES	YES	YES	YES
MaE2	77	NO	NO	NO	NO	YES	YES	NO	NO
PaA	73	NO	NO	NO	NO	YES	YES	NO	NO
Sn	92	NO	NO	NO	NO	YES	YES	NO	YES
PcC2	56	NO	NO	NO	NO	NO	YES	NO	NO
Cc	22	NO	NO	NO	NO	YES	NO	NO	NO
Ft	36	NO	YES	NO	YES	NO	NO	NO	NO
AmB	79	YES	YES	NO	NO	NO	NO	NO	NO
GuF	71	YES	YES	NO	NO	NO	NO	NO	NO
Mining	57	NO	YES	NO	NO	NO	NO	NO	NO
Tf	15	YES	YES	NO	NO	YES	NO	NO	NO

Salinas	64	YES	YES	NO	NO	NO	NO	NO	NO
Unsur	89	NO	NO	NO	NO	YES	NO	YES	YES
PoA	54	NO	YES	NO	NO	NO	NO	NO	NO
PaB	28	NO	NO	NO	NO	YES	NO	NO	NO
PcC2	86	NO	NO	NO	NO	YES	NO	NO	NO
Sc	78	NO	NO	YES	YES	YES	NO	YES	YES
GuD	67	YES	NO	NO	NO	NO	NO	NO	NO
AcE2	70	YES	NO	NO	NO	NO	NO	NO	NO
Vo	41	YES	NO	YES	NO	NO	NO	NO	YES
SmE	38	YES	NO	NO	NO	NO	NO	NO	NO
AsB	29	YES	NO	NO	NO	NO	NO	NO	NO
Ao	68	YES	NO	NO	NO	NO	NO	NO	NO
SsB	13	YES	NO	NO	NO	YES	NO	NO	NO
Se	35	NO	NO	YES	YES	NO	NO	YES	NO
URBAN AREA	96	NO	YES	NO	YES	NO	NO	NO	NO
Fe	97	NO	NO	YES	YES	NO	YES	NO	YES

PONCE SOIL SURVEY							
Type of Soil	SHADING #	GTP	PJD	PSI	CMTR	VILLAT	CERRIT
Jg	35	YES	YES	YES	YES	YES	YES
FtB	30	YES	YES	YES	NO	NO	YES
CoE	19	YES	YES	YES	YES	YES	YES
FtC2	31	YES	YES	YES	NO	NO	YES
CoF2	20	YES	YES	YES	YES	YES	YES
AgF	7	YES	YES	YES	NO	YES	YES
AgD	6	YES	YES	YES	NO	YES	YES
YcB	66	YES	YES	NO	NO	NO	YES
Sa	71	YES	YES	YES	NO	NO	NO
YcC	67	YES	YES	YES	NO	YES	NO
JzD	42	YES	YES	NO	NO	NO	YES
JzE	43	YES	YES	NO	NO	NO	NO
JnC	40	YES	YES	YES	YES	YES	YES
CoD	18	YES	YES	YES	YES	YES	YES
AhF	8	YES	YES	YES	YES	YES	YES
WATER	4	YES	YES	YES	NO	YES	YES
Ct	10	YES	YES	YES	NO	NO	NO
Te	78	YES	YES	YES	NO	NO	NO
Hz	26	YES	YES	YES	NO	NO	NO
Mr	51	YES	YES	YES	NO	NO	NO
Se	76	YES	YES	NO	NO	NO	NO
To	92	YES	NO	NO	NO	YES	NO
QeD2	54	YES	NO	NO	NO	YES	NO
QeF2	55	YES	NO	NO	YES	YES	YES
MsC	60	YES	NO	NO	YES	NO	NO
MtF2	62	YES	NO	NO	YES	YES	YES
TuF	94	YES	NO	NO	NO	NO	NO
UNSUR	89	YES	NO	YES	YES	YES	YES
Cx	32	YES	YES	YES	NO	NO	NO
EnC	21	YES	NO	NO	NO	NO	NO
Ma	79	YES	YES	YES	NO	NO	NO
Tf	83	YES	YES	YES	NO	NO	NO
LAND FILL	91	NO	YES	NO	NO	NO	NO
PaB	22	NO	YES	YES	NO	NO	YES
GoF	23	NO	YES	NO	NO	YES	NO
LnC2	68	NO	YES	YES	YES	YES	YES
LnB	98	NO	YES	YES	YES	YES	YES
Cr	34	NO	YES	NO	NO	NO	YES
GRAVEL PIT	92	NO	YES	YES	NO	NO	YES
GoF2	90	NO	YES	NO	NO	NO	NO
Fe	70	NO	YES	YES	NO	NO	NO
Hy	47	NO	YES	YES	NO	NO	NO
Rw	46	NO	YES	YES	NO	NO	YES
Cy	24	NO	YES	YES	YES	NO	YES
G.P.	99	NO	NO	YES	NO	YES	NO
MuF2	44	NO	NO	NO	YES	YES	YES
MuE2	80	NO	NO	NO	YES	YES	YES
MuD2	48	NO	NO	NO	YES	YES	YES

CbF2	97	NO	NO	NO	YES	YES	YES
CdF	5	NO	NO	NO	YES	YES	YES
QeE2	17	NO	NO	NO	NO	YES	YES
Re	29	NO	NO	NO	NO	YES	YES
Q.U.	100	NO	NO	NO	NO	YES	NO
MtE2	69	NO	NO	NO	NO	NO	YES
MeF2	72	NO	NO	NO	NO	NO	YES
CuF2	58	NO	NO	NO	NO	NO	YES
JnC2	15	NO	NO	NO	YES	NO	NO
CoF	36	NO	NO	NO	NO	YES	NO

HUMACAO SOIL SURVEY					
Type of Soil	SHADING #	GUAYART	GUYT	SAL2T	SALT
DrF	30	YES	YES	YES	YES
DgF2	20	YES	YES	NO	NO
Rs	64	YES	YES	YES	YES
Cn	23	YES	YES	YES	YES
UNSUR	89	YES	YES	YES	YES
AmB	80	YES	YES	YES	YES
GyC2	36	YES	YES	NO	NO
Gm	31	YES	YES	YES	YES
JaB	34	YES	YES	YES	YES
DeE2	19	NO	YES	NO	YES
DeC2.	18	NO	YES	YES	YES
McB	71	NO	YES	NO	NO
JaC2	54	YES	YES	YES	YES
VvB	96	NO	YES	NO	YES
CIB	92	NO	YES	YES	YES
VvA	32	NO	YES	NO	NO
PIB	43	NO	YES	YES	YES
McA	55	NO	YES	NO	NO
Va	66	NO	YES	NO	NO
Ar	79	NO	YES	YES	YES
Vs	95	NO	YES	NO	YES
WATER	4	NO	YES	NO	YES
Po	98	NO	YES	NO	YES
Ce	94	NO	YES	NO	YES
Ts	16	NO	YES	NO	YES
Tf	15	NO	YES	NO	YES
An	48	NO	YES	YES	YES
MrB	42	NO	YES	NO	YES
Sm	14	NO	YES	NO	NO
Ad	90	NO	YES	NO	NO
Cm	10	NO	YES	NO	NO
AmC2	47	YES	YES	YES	YES
LsF2	100	YES	NO	NO	NO
CbF2	91	YES	NO	YES	NO
LsE2	93	YES	NO	NO	NO
LsD	2	YES	NO	NO	NO
NaF2	8	YES	NO	NO	NO
PaF2	46	YES	NO	NO	NO
NaE2	68	YES	NO	YES	NO
PmE2	53	YES	NO	NO	NO
MuE2	45	YES	NO	NO	NO
MuD2	12	YES	NO	NO	NO
DeE2	75	YES	NO	YES	NO
FrA	24	NO	NO	NO	YES
Cf	40	NO	NO	NO	YES
PrC2	70	NO	NO	NO	YES
FrB	78	NO	NO	NO	YES

Appendix 4: Fundamentals of Remote Sensing Workshop

- Fundamentals of Remote Sensing Workshop Schedule
- List of Participants at the Fundamentals of Remote Sensing Workshop during the week of July 10 to 14, 1995
- List of Participants at the Fundamentals of Remote Sensing Workshop during the week of August 7 to 11, 1995
- Evaluations Forms filled out by the participants

Fundamental of Remote Sensing Workshop

Schedule

Day One

Start at 8:15 a.m.
Instructions for the week, breaks, participation and other requirements
Why a Fundamental of Remote Sensing Workshop (FRSW) and their relationship with NASA?
What is NASA?
Video: NASA the 25th year
Duration 50 minutes
Break 10:00 to 10:15 a.m.
What is Remote Sensing?

Lunch 11:45 a.m. a 1:00 p.m.

Basic Principles of Remote Sensing
Break 3:00 p.m. to 3:15 p.m.
Photographic Sensors
End 5:00 p.m.

Day Two

Start 8:15 a.m.
Principles of Photointerpretation
Break 10:00 to 10:15 a.m.
Exercise of Photointerpretation

Lunch 11:45 a.m. a 1:00 p.m.

Land Uses Maps of Guánica Dry Forest by Remote Sensing
Break 3:00 p.m. a 3:15 p.m.
NASA Grant NAG13-17
Video: Sentinels in Space
Duration 20 minutes
End 5:00 p.m.

Day Three

Visit to the Guánica Dry Forest
Departure at 7:30 a.m.
Return at 5:00 p.m.

Day Four

Start 8:15 a.m.
Video: LANDSAT: 15 years of Learning Duration 15 minutes
Sensors and Platforms
Break 10:00 a 10:15 a.m.
Remote Sensing Tutor at CAIDEL

Lunch 11:45 a.m. a 1:00 p.m.

Visit to LARSIP at S-222
Break 3:00 p.m. a 3:15 p.m.
continues the visit to LARSIP
End 5:00 p.m.

Day Five

Start 8:15 a.m.
Mission to Planet Earth
Video: Climate Factor
Duration 30 minutes
Video: Beyond the Clouds-The Upper Atmosphere
Duration 10 minutes
Break 10:00 a 10:15 a.m.
El Niño
Global Warming
Clouds and the Energy Cycle

Lunch 11:45 a.m. a 1:00 p.m.

Biosphere
Ozone:What is it, and why do we care about it?
Volcanoes and Global Climate Change
Video: In the Shadow of Versuvius
Duration 60 minutes
Break 3:00 p.m. a 3:15 p.m.
Summary
Evaluation of the workshop
End 5:00 p.m.

List of Participants at the Fundamental of Remote Sensing Workshop during the week of July 10 to 14, 1995

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List of Participants at the Fundamental of Remote Sensing Workshop during the week of August 7 to 11, 1995

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Fundamentals of Remote Sensing Workshop

Fecha: 14-julio-1995 Lugar: Ingeniería Civil 012

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	✓				
2. Organización del contenido	✓				
3. Participación de los asistentes		✓			
4. Dominio del tema por los recursos	✓				
5. Técnicas y materiales utilizados en la actividad	✓				
6. Utilización del tiempo	✓				
7. La actividad satisfizo mis expectativas sobre el tema	✓				

Comentarios: Todo estuvo excelente realmente, aprendí mucho & me interesa mucho esta área de foto interpretación, remote sensing y digitalización. Sería una buena idea incorporar y dar cursos de estos campos y tecnologías en los cursos graduados en el departamento además

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HOJA DE EVALUACION

Le agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Fundamentos al Remote Sensing Workshop

Fecha: 7/10-14/95 Lugar: Ingeniería Civil

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	X				
2. Organización del contenido	X				
3. Participación de los asistentes	X				
4. Dominio del tema por los recursos	X				
5. Técnicas y materiales utilizados en la actividad	X				
6. Utilización del tiempo	X				
7. La actividad satisfizo mis expectativas sobre el tema	X				

Comentarios: Este taller fue algo muy interesante y ayudó a ampliar mis conocimientos más de lo que esperaba. Los profesores son muy buenos y me gustó mucho el ambiente que desarrollaban en el salón diariamente.

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Fundamentos de Percepción Remota

Fecha: 7/10-14/95 Lugar: I. Civil

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	X				
2. Organización del contenido	X				
3. Participación de los asistentes	X				
4. Dominio del tema por los recursos	X				
5. Técnicas y materiales utilizados en la actividad	X				
6. Utilización del tiempo	X				
7. La actividad satisfizo mis expectativas sobre el tema	X				

Comentarios: Considero que fue una buena para mi persona. Y deben seguir ofreciendo mas talleres de este tipo, para ampliar los conocimientos del estudiante

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Fundamentals of Remote Sensing Workshop.

Fecha: julio 10 - 14 de 1995 Lugar: Ing. Civil

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	✓				
2. Organización del contenido		✓			
3. Participación de los asistentes	✓				
4. Dominio del tema por los recursos	✓				
5. Técnicas y materiales utilizados en la actividad		✓			
6. Utilización del tiempo		✓			
7. La actividad satisfizo mis expectativas sobre el tema	✓				

Comentarios: Ayudó a ampliar mi concepto de lo que es la Percepción Remota. Resalta que es un campo mucho más abarcador de lo que pensaba y tiene una infinidad de aplicaciones que desconocía.

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Fundamentos de Persepción Remota

Fecha: 7/14/95 (10-14) Lugar: Edificio de Ing. Civil CI-12

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	X				
2. Organización del contenido	X				
3. Participación de los asistentes	X				
4. Dominio del tema por los recursos	X				
5. Técnicas y materiales utilizados en la actividad	X				
6. Utilización del tiempo	X				
7. La actividad satisfizo mis expectativas sobre el tema	X				

Comentarios: La presentación del material fue muy buena. Me hubiese gustado que se hiciera con ejercicio específica de como utilizan los nuevos métodos de sistemas de información geográfica, de digitalización

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Talles de fundamentos de Percepción Remota

Fecha: 10 - 14 julio - '95 Lugar: Dpto. Ing. Civil RUM

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	✓				
2. Organización del contenido	✓				
3. Participación de los asistentes		✓			
4. Dominio del tema por los recursos	✓				
5. Técnicas y materiales utilizados en la actividad	✓				
6. Utilización del tiempo	✓				
7. La actividad satisfizo mis expectativas sobre el tema	✓				

Comentarios: La actividad fue de muy buen provecho para nosotros los estudiantes. El departamento debería de seguirnos motivando con actividades como ésta.

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HOJA DE EVALUACION

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Nombre de la Actividad: Taller sobre fundamentos de Persepción Remota

Fecha: 10 - 14 de julio 1995 Lugar: Departamento Ing. Civil

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	✓				
2. Organización del contenido	✓				
3. Participación de los asistentes		✓			
4. Dominio del tema por los recursos	✓				
5. Técnicas y materiales utilizados en la actividad	✓				
6. Utilización del tiempo	✓				
7. La actividad satisfizo mis expectativas sobre el tema		✓			

Comentarios: El taller despertó más interes en mí sobre mi area de estudio.

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Taller sobre Fundamentos de Percepción Remota

Fecha: 10 - 14 julio Lugar: Ing. Civil - R.U.M.

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido		X			
2. Organización del contenido		X			
3. Participación de los asistentes		X			
4. Dominio del tema por los recursos	X				
5. Técnicas y materiales utilizados en la actividad	X				
6. Utilización del tiempo		X			
7. La actividad satisfizo mis expectativas sobre el tema	X				

Comentarios: Muy buen trabajo. Me gustó mucho la organización de los temas discutidos pues cada conferencia y tema continuaba el anterior de modo que nunca me sentí perdida. Continúen realizando este tipo de actividad, pues sirve de gran →

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HOJA DE EVALUACION

Le agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Fundamentos de Fotografía Aérea

Fecha: 10 — 14 julio/95 Lugar: Ed de Ing Civil CI12

Favor de evaluar esta actividad utilizando la siguiente escala:

(5) Excelente
4 Muy buena
3 Buena
2 Regular
1 Deficiente

	5	4	3	2	1
1. Importancia del contenido	X				
2. Organización del contenido	X				
3. Participación de los asistentes	X				
4. Dominio del tema por los recursos	X				
5. Técnicas y materiales utilizados en la actividad	X				
6. Utilización del tiempo	X				
7. La actividad satisfizo mis expectativas sobre el tema	X				

Comentarios: Debería extenderse un poco más para incluirle un el aprendizaje con los métodos modernos de información geográfica computalizados. Y también más "field trips", ¿por qué no? Sería bueno que este proyecto continuará para que otros jóvenes puedan disfrutar del mismo. Debería servir como

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HOJA DE EVALUACION

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Nombre de la Actividad: Fundamental of Remote Sensing Workshop

Fecha: 10 - 14 de julio de 1995 Lugar: dep Ingenieria Civil

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	✓				
2. Organización del contenido	✓				
3. Participación de los asistentes		✓			
4. Dominio del tema por los recursos	✓				
5. Técnicas y materiales utilizados en la actividad	✓				
6. Utilización del tiempo	✓				
7. La actividad satisfizo mis expectativas sobre el tema	✓				

Comentarios: Este taller amplia los conocimientos sobre "remote Sensing" a los estudiantes ademar de mostrarles diferentes e inovadores Areas de trabajo.

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Taller sobre fundamentos de Percepción Remota

Fecha: 7-11 de agosto de 1995. Lugar: Lab. de Agrimensura

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	X				
2. Organización del contenido	X				
3. Participación de los asistentes	X				
4. Dominio del tema por los recursos	X				
5. Técnicas y materiales utilizados en la actividad	X				
6. Utilización del tiempo	X				
7. La actividad satisfizo mis expectativas sobre el tema	X				

Comentarios: _____

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: *Taller sobre Fundamentos de Percepción Remota*

Fecha: *7 - 11 de agosto 1995* Lugar: *Lab. de Agrimensura y Top*

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	X				
2. Organización del contenido	X				
3. Participación de los asistentes	X				
4. Dominio del tema por los recursos	X				
5. Técnicas y materiales utilizados en la actividad	X				
6. Utilización del tiempo	X				
7. La actividad satisfizo mis expectativas sobre el tema	X				

Comentarios: *Sería muy buena que se siguiera ofreciendo este tipo de talleres sobre diferentes temas ya que son de buen provecho para nuestro futuro.*

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Taller sobre fundamentos de Percepcion Remota

Fecha: 7-11 de agosto-95 Lugar: Las. Agrimensura CE-12

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	✓				
2. Organización del contenido	✓				
3. Participación de los asistentes	✓				
4. Dominio del tema por los recursos	✓				
5. Técnicas y materiales utilizados en la actividad	✓				
6. Utilización del tiempo	✓				
7. La actividad satisfizo mis expectativas sobre el tema	✓				

Comentarios: Me gustaria obtener mas literatura sobre el tema. El taller deberia repetirse en otros años y llevarlo a escuelas publicas del pais.

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Taller sobre fundamentos de programación computadoras

Fecha: 7-11 de agosto de 1995 Lugar: Lab. de Agricultura

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	✓				
2. Organización del contenido	✓				
3. Participación de los asistentes			✓		
4. Dominio del tema por los recursos	✓				
5. Técnicas y materiales utilizados en la actividad		✓			
6. Utilización del tiempo	✓				
7. La actividad satisfizo mis expectativas sobre el tema	✓				

Comentarios: Dar mayor promoción al Taller. En invitación promocional a los candidatos al mismo

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HOJA DE EVALUACION

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Nombre de la Actividad: Taller sobre fundamentos de Percepción Remota

Fecha: 7-11 agosto - 95 Lugar: Lab de Agrimensura

Favor de evaluar esta actividad utilizando la siguiente escala:

(5)	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	✓				
2. Organización del contenido	✓				
3. Participación de los asistentes	✓				
4. Dominio del tema por los recursos	✓				
5. Técnicas y materiales utilizados en la actividad	✓				
6. Utilización del tiempo	✓				
7. La actividad satisfizo mis expectativas sobre el tema	✓				

Comentarios: _____

_____

_____

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Taller de Instrumentos de Fortificación Portátil

Fecha: 7-11 agosto de 1995 Lugar: Laboratorio de Agrimensura

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	✓				
2. Organización del contenido		✓			
3. Participación de los asistentes	✓				
4. Dominio del tema por los recursos	✓				
5. Técnicas y materiales utilizados en la actividad	✓				
6. Utilización del tiempo	✓				
7. La actividad satisfizo mis expectativas sobre el tema	✓				

Comentarios: _____

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Nombre de la Actividad: Taller de Percepción Remota

Fecha: 7 - 11 de agosto 1995. Lugar: RUM / Ing Civil

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	✓				
2. Organización del contenido	✓				
3. Participación de los asistentes		✓			
4. Dominio del tema por los recursos	✓				
5. Técnicas y materiales utilizados en la actividad	✓				
6. Utilización del tiempo	✓				
7. La actividad satisfizo mis expectativas sobre el tema	✓				

Comentarios: Repitan este tipo de Taller más a menudo.

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Taller sobre Fundamentos de Percepción Remota

Fecha: 7 al 11 de Agosto 195 Lugar: Lab de Agrimensura

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	X				
2. Organización del contenido	X				
3. Participación de los asistentes	X				
4. Dominio del tema por los recursos	X				
5. Técnicas y materiales utilizados en la actividad	X				
6. Utilización del tiempo	X				
7. La actividad satisfizo mis expectativas sobre el tema		X			

Comentarios: Encuentro que el taller fue de gran interes. Pero me hubiese gustado poder haber tenido más oportunidad en el proceso de analisis de imagenes y fotografias

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HOJA DE EVALUACION

Te agradeceremos cumplimentes la siguiente hoja de evaluación.

Nombre de la Actividad: Taller sobre Fundamentos de Percepción Remota.

Fecha: 7-11 de agosto 1995 Lugar: Laboratorio de Aguadilla

Favor de evaluar esta actividad utilizando la siguiente escala:

5	Excelente	2	Regular
4	Muy buena	1	Deficiente
3	Buena		

	5	4	3	2	1
1. Importancia del contenido	✓				
2. Organización del contenido	✓				
3. Participación de los asistentes		✓			
4. Dominio del tema por los recursos		✓			
5. Técnicas y materiales utilizados en la actividad	✓				
6. Utilización del tiempo	✓				
7. La actividad satisfizo mis expectativas sobre el tema	✓				

Comentarios: Pienso que esta clase de actividades se deben repetir con otros temas. Este taller me ha despertado la curiosidad y me gustaría llegar a profundizar más en el tema de Percepción Remota.

Departamento de Ingeniería Civil
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HOJA DE EVALUACION

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Nombre de la Actividad: Taller sobre Fundamentos de Percepción Remota

Fecha: 7-11 agosto de 1995 **Lugar:** P.U.M. Mayagüez

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6. Utilización del tiempo	✓				
7. La actividad satisfizo mis expectativas sobre el tema	✓				

Comentarios: Espero que este taller sea ofrecido durante los proximos años, para que las personas como yo aprendan algo nuevos sobre lo que he aprendido esta semana!

Gracias!