APPENDIX B

ALTERNATIVE MATERIALS FOR STORM SEWERS

CITY OF CHARLESTON

MASTER DRAINAGE AND FLOODPLAIN MANAGEMENT PLAN

APPENDIX B

ALTERNATIVE MATERIALS FOR STORM SEWERS

I. INTRODUCTION

Davis & Floyd, Inc. was requested by the City of Charleston to investigate available pipe materials for utilization in the construction of storm sewers and culverts and to make recommendations concerning their use as a part of the City of Charleston Master Drainage and Flood Plain Management Plan. The purpose of this investigation is to identify "equals" for pipe materials to be utilized in the construction of storm sewers and culverts which are effectively resistant to the corrosive soil and effluent characteristics of the area, are readily available and are suitable for installation by City employees and private contractors. A variety of pipe materials were studied to ascertain their record of durability in local installations and in existing drainage systems comparable to the City of Charleston environment and to establish how each type compares on an "or equal" basis.

This study included an analysis of available information on the soil characteristics, topography and weather records of the area to establish bases for comparative analysis of each material.

Appendix C lists the soils existing in the study area and summaries the extent of incidence of each soils series and its characteristics, including hydrological group, reaction (pH value) and resistivity.

II. GENERAL

The types of pipe material studied are:

A. Reinforced concrete pipe.

B. Corrugated metal pipe as follows:

1. galvanized steel
2. galvanized steel with full asphalt coating
3. galvanized steel with full asphalt coating and paved invert
4. galvanized steel with full asphalt coating and fully paved
5. asbestos bonded steel
6 asbestos bonded steel with asphalt coating
7. aluminized steel
8. plastic coated steel
9. aluminum

C. Polyvinyl chloride (PVC) pipe.

Reports of independent studies conducted by several other states' agencies concerning the suitability of the different type materials currently used for the construction of culverts and storm sewers were utilized in this study. Other resource data included information provided by pipe manufacturers, interviews with Federal Highway Administration, State Highway department and local public works personnel, field investigations, and past experience of Davis & Floyd engineers.

Selection of a specific pipe material to be used for an installation requires determination that the pipe characteristics fall within the bounds of several parameters, each of which may play a greater or less significant role in each given circumstance.

Durability of the pipe material, i.e., its resistance to failure from the exterior, caused by corrosive effects of the surrounding soil, or, failure from the interior, caused by the effects of the effluent carried by the pipe, ultimately plays the most significant role in the majority of situations. Cost effectiveness is directly influenced by the expected useful life of a pipe installation.

The data in Appendix C, Soil Characteristics, shows that the soil in the area is basically acidic and the soil resistivity is low, a combination which creates a corrosive environment for the culvert and storm sewer systems. The relatively flat topography of the study area leads to occurrences of tidal salt and brackish waters entering and standing in storm sewers and culverts in the area. The presence of salt water establishes a highly corrosive environment in the areas in which this occurs. These two factors, moderate soil acidity and low resistivity, combine to create a relatively highly corrosive environment into which the culvert and storm sewer systems must be placed and maintained.

III. PIPE MATERIALS

Generally, in the Charleston area, storm sewers and culverts are constructed of corrugated metal or reinforced concrete pipe with each having relative advantages and disadvantages, including the following:

REINFORCED CONCRETE PIPE (RCP)

Advantages	Disadvantages
1. Proven reliability.	1. Heavy weight, especially significant in larger diameters.
2. Life expectancy of 100 years or more.	2. Separation of joints likely to occur where installed in soils subject to subsistence or consolidation.
3. Good hydraulic characteristics.	
4. Local availability.	
5. High external load resistance.	

TABLE 1

CHARLESTON AREA SOIL CHARACTERISTICS

SOIL ASSOCIATION	% LAND AREA	SOIL SERIES	% EXTENT (WITHIN ASSOCIATION)	REACTION (pH)	HYDROLOGICAL GROUP (EACH SERIES)	COMPOSITE HYDROLOGICAL GROUP ASSOCIATION: GROUP	COMPOSITE HYDROLOGICAL GROUP ASSOCIATION: % EXTENT
3- Chipley-Lakeland	5	Chipley	66	5.1/5.5	A	A	88%
		Lakeland	23	4.5/5.5	A		
		Rutledge		5.1/5.5	B	B	12%
		Osier	11	4.5/5.0	A		
		Wagram		5.1/5.5	A		
5- Wando-Seabrook	10	Wando	51	6.1/6.5	A	A	55%
		Seabrook	31	5.1/6.0	C	B	30%
		Kiawah		5.1/6.0	B	C	15%
		Rutledge		5.1/5.5	B		
		Dawhoo	18	6.1/6.5	B		
		Charleston		4.5/5.5	D		
		Wagram		5.1/5.5	A		
		Edisto		4.5/5.5	C		
6- Kiawah-Seabrook-Dawhoo	10	Kiawah	48	5.1/6.0	B	B	70%
		Seabrook	19	5.1/6.0	C	C	30%
		Dawhoo	17	6.1/6.5	B		
		Rutledge		4.5/5.0	B		
		Wando	16	6.1/6.5	A		
		Edisto		4.5/5.1	C		
		Yonges		4.5/8.4	D		
7- Yonges-Hockley-Edisto	30	Yonges	31	5.6/8.4	D		
		Hockley	21	4.5/5.5	B	B	28%
		Edisto	14	4.5/5.5	C	C	14%
		Charleston		4.5/5.5	D	D	58%
		Meggett		4.5/7.3	D		
		Santee	34	5.1/6.5	D		
		Wadmalaw		4.5/8.4	D		
		Wicksburg		4.5/6.5	B		
10- Tidal Marsh	20	Tidal Marsh	70	4.5/7.0	D	A	18%
		Capers	18	5.6/6.5	D		
		Coastal Beaches		5.6/6.0	A		
		Dune Land		5.6/6.0	A	D	82%
		Crevasse	12	5.1/5.5	A		
		Dawhoo		6.5/6.5	B		
		Pamlico		4.5/6.0	D		
		Rutledge		5.1/5.5	B		
11- Mine Pits, Dumps, Made Land	10	Pits & Dumps (Old Phosphate Mines)	70		D	D	100%
		Made Land	30				
Peninsula	15	(See Text)				A	70%
						C	30%

TABLE 2

HYDROLOGIC SOIL GROUPS

The soils of the study area have been classified into four hydrologic soil groups. The hydrologic soil groups, according to their infiltration and transmission rates, are:

A. (Low runoff potential). Soils having high infiltration rates even when thoroughly wetted. These consist chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission in that water readily passes through them.

B. Soils having moderate infiltration rates when thoroughly wetted. These consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Soils having slow infiltration rates when thoroughly wetted. These consist chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D. (High runoff potential). Soils having very slow infiltration rates when thoroughly wetted. These consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

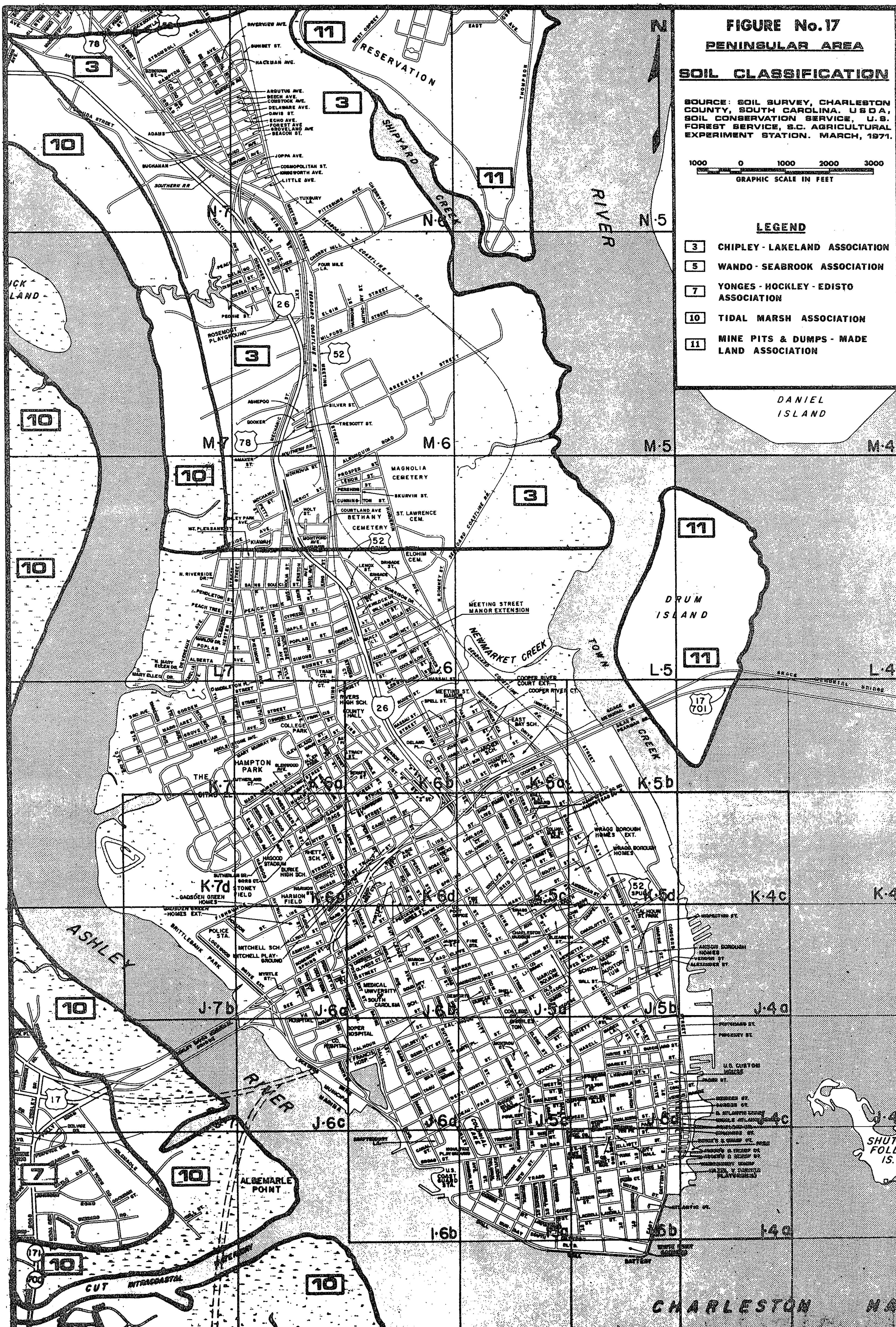
FIGURE No. 17
PENINSULAR AREA
SOIL CLASSIFICATION
SOURCE: SOIL SURVEY, CHARLESTON COUNTY, SOUTH CAROLINA. USDA, SOIL CONSERVATION SERVICE, U.S. FOREST SERVICE, S.C. AGRICULTURAL EXPERIMENT STATION. MARCH, 1971.
1000 0 1000 2000 3000
GRAPHIC SCALE IN FEET
LEGEND
3 CHIPLEY - LAKELAND ASSOCIATION
5 WANDO - SEABROOK ASSOCIATION
7 YONGES - HOCKLEY - EDISTO ASSOCIATION
10 TIDAL MARSH ASSOCIATION
11 MINE PITS & DUMPS - MADE LAND ASSOCIATION
N
DANIEL ISLAND
DRUM ISLAND
RESERVATION
SHIPYARD CREEK
RIVER
NEWMARKET CREEK
TOWN CREEK
ASHLEY RIVER
CHARLESTON
ALBEMARLE POINT
CUT INTRACOASTAL
HAMPTON PARK
COLLEGE PARK
MAGNOLIA CEMETERY
BETHANY CEMETERY
MEETING STREET MANOR EXTENSION
MEDICAL UNIVERSITY OF SOUTH CAROLINA
SHUTE FOLL IS.

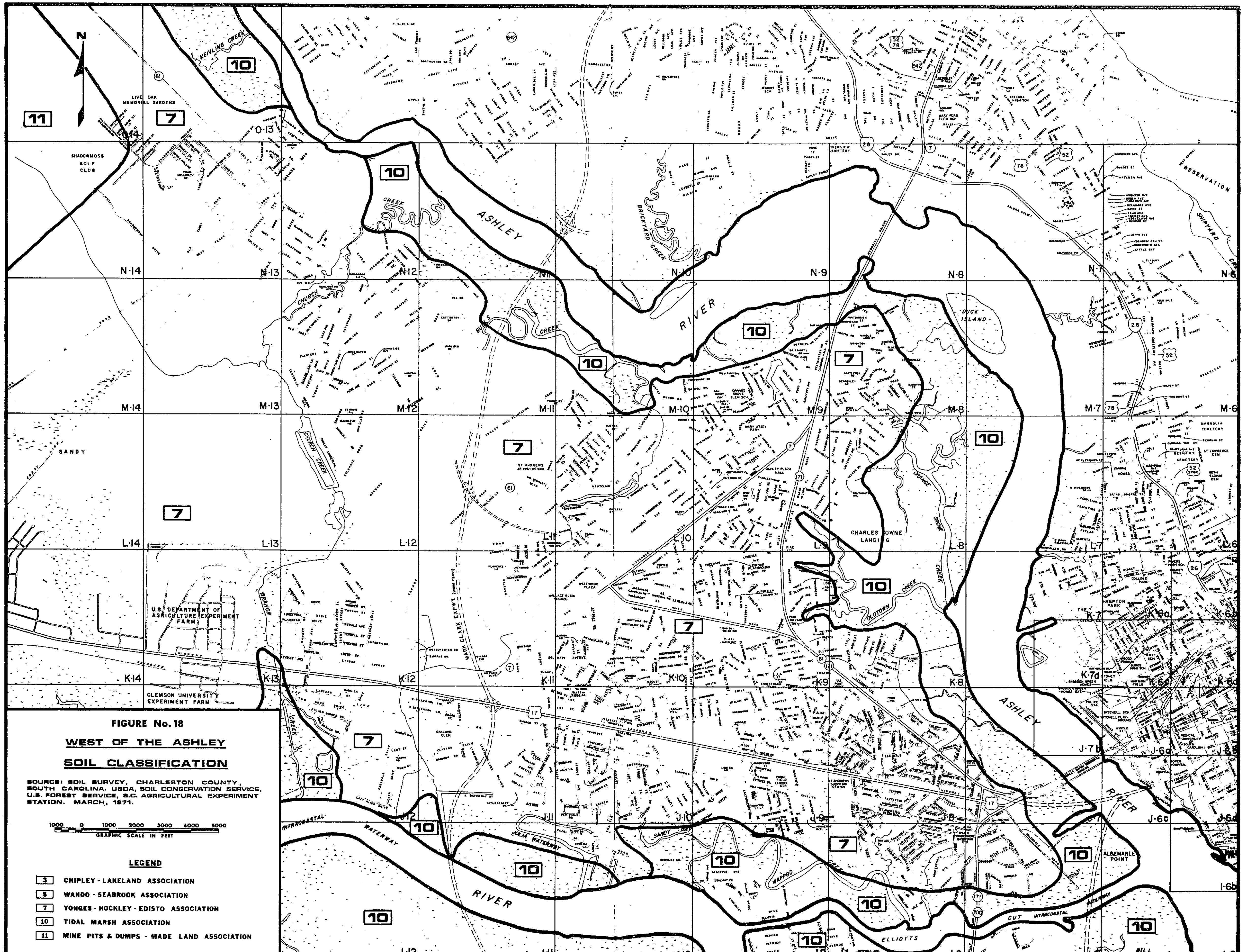

FIGURE No. 18

WEST OF THE ASHLEY

SOIL CLASSIFICATION

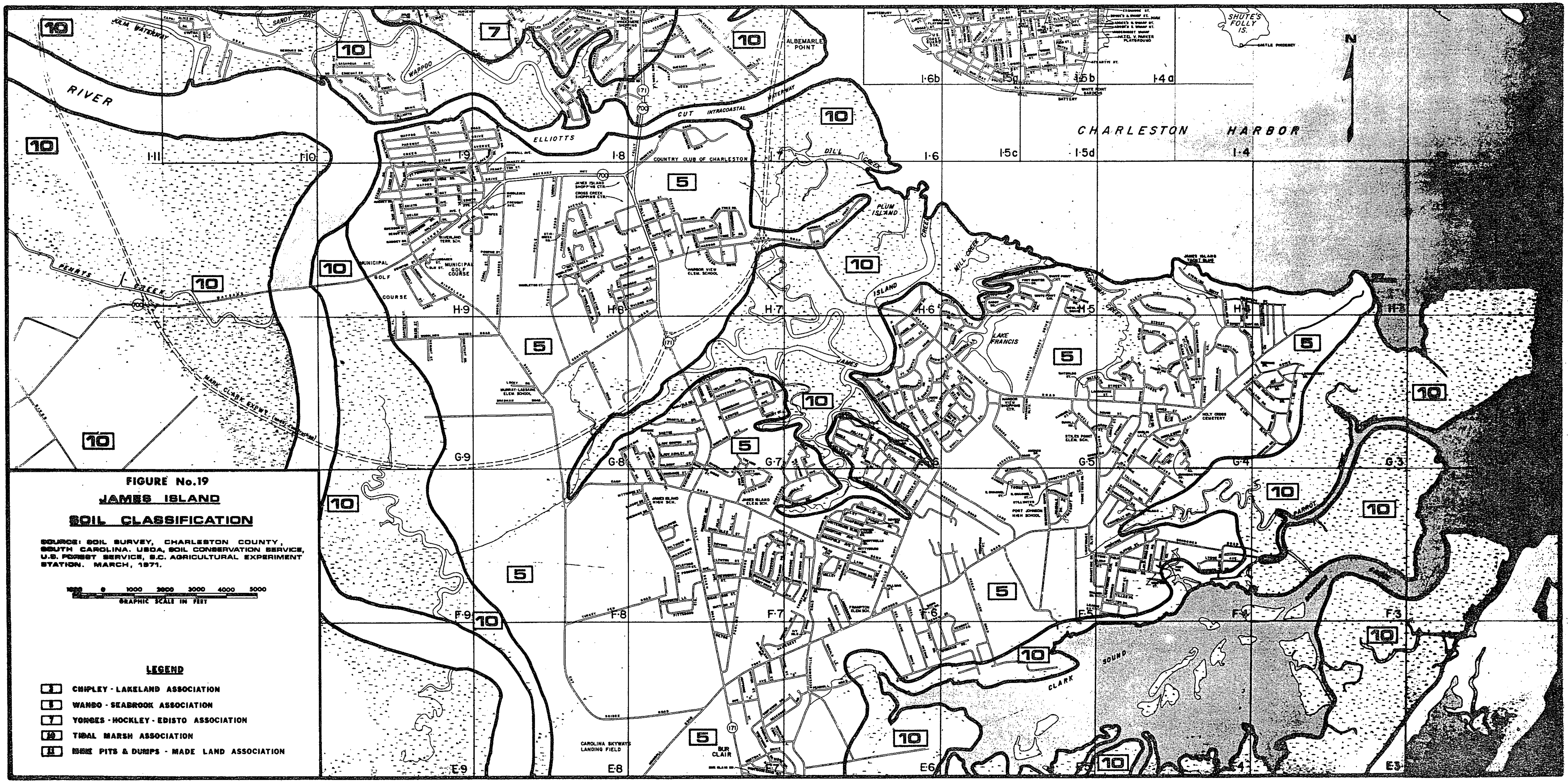

FIGURE No.19

JAMES ISLAND

SOIL CLASSIFICATION

SOURCE: SOIL SURVEY, CHARLESTON COUNTY, SOUTH CAROLINA. USDA, SOIL CONSERVATION SERVICE, U.S. FOREST SERVICE, S.C. AGRICULTURAL EXPERIMENT STATION. MARCH, 1971.

respectively, which will provide a product equal to reinforced concrete pipe.

As stated previously, a discussion of each type of corrugated metal pipe follows:

a. Galvanized Steel. Plain galvanized steel is unacceptable for use in this area. This is justified on the basis of:

1. past experience in this area;

2. the Washington State Study which found the plain galvanized steel pipe to be unacceptable in areas which have a large amount of precipitation;

3. the Colorado Study rated it as the type pipe most susceptible to corrosion;

4. the Georgia Department of Transportation requires coating and paving of all storm drains based on their "Performance Evaluation of Corrugated Metal Culverts in Georgia;" and

5. the New York Study which recommended that galvanized steel be coated in order to have a reasonable life expectancy.

b. Galvanized Steel with Full Asphaltic Coating. Galvanized steel with full asphalt coating is satisfactory in this area under certain circumstances. The asphalt coating gives corrugated steel pipe a life expectancy of ten plus years over plain galvanized steel pipe according to the results of the tests conducted by the American Iron and Steel Institute and as substantiated by most independent reports on the subject. However, the life expectancy of asphalt coated pipe is limited and therefore should not be used under certain circumstances, such as:

1. culverts under embankments of more than ten feet where replacement would be difficult; and

2. pipe in any type of closed drainage system, or in any other type of installation where failure would be difficult or expensive to correct such as culverts under major streets or highways.

Conditions where plain asphalt coated pipe would be acceptable due to its ease of installation, resistance to breakage, light weight, and its ability to be removed without damage would be:

1. culverts under minor streets and secondary roads where it will not be expensive or difficult to correct failures; and

2. temporary culverts utilized during construction activities.

Based on the above, it is recommended that asphalt coated pipe be utilized as an alternate to reinforced concrete pipe using the minimum gages shown in Table P-3, "Minimum Gage Sizes for Corrugated Steel Pipe," under the above acceptable conditions, provided the pipe has sufficient cover as shown in Table P-3, and provided the corrugated metal pipe is furnished in the equivalent reinforced concrete pipe diameters as shown on Table P-2 "Equivalent Pipe Diameters for Reinforced Concrete and Corrugated Metal Pipes." It is not recommended that this type pipe be utilized in tidally affected areas based on past experience and the corrugated pipe manufacturers' recommendations.

c. Galvanized Steel with Full Asphalt Coating and Paved Invert was found to be superior to plain asphalt coated pipe according to tests conducted by the Washington State Highway Department and the Georgia Department of Transportation. According to their findings, the majority of the failures using plain asphalt coated pipe occurred in the invert of the pipe. "Invert paving would clearly add at least 30 years of service and make the use of metal culverts feasible in a corrosive environment," according to these reports. Based on these findings and backed by other similar reports, it is recommended that galvanized steel with full asphalt coating and paved inverts be used as an alternate to reinforced concrete pipe provided the equivalent reinforced concrete pipe diameters found in Table P-2 are used, and the pipe has the minimum gage thickness and sufficient cover as provided for in Table P-3. It is not recommended that this type pipe be used in tidally affected environments, however, based on past experience and the corrugated pipe manufacturers' recommendations.

d. Galvanized Steel with Full Asphalt Coating and Fully Paved has the advantage aforementioned for paved invert pipe, with the additional advantage of good hydraulic characteristics which reduce the friction factor and thereby increase the quantity of flow through a given size pipe. The flow through a given diameter fully paved corrugated steel pipe is as great as the same diameter reinforced concrete pipe. Therefore, it is recommended that galvanized steel with full asphalt coating and fully paved corrugated metal pipe be utilized as an alternate to reinforced concrete pipe, provided the pipe has the minimum gage thickness and sufficient cover as provided for in Table P-3. It is not recommended that this type pipe be used in tidally affected environments, however, based on past experience and the corrugated pipe manufacturers' recommendations.

e. Asbestos Bonded Steel Pipe is recommended by many sources for use in salt water environments. However, it was determined by tests conducted by the Colorado Highway Department that without additional coating the asbestos had a tendency to wear off rapidly. Therefore, due to the high cost of asbestos bonded pipe and its tendency to wear off rapidly, it is recommended that uncoated asbestos bonded steel pipe not be utilized.

f. Asbestos Bonded with Asphalt Coating Corrugated Steel Pipe is recommended by many sources for use in salt water environments and has a good record of performance. This type could be utilized in tidal outfalls, provided the pipe has the minimum gage thickness and sufficient cover as provided for on Table P-3 and is provided in the equivalent reinforced concrete pipe diameters found in Table P-2, when used as an alternate to reinforced concrete pipe.

g. Aluminized Corrugated Steel Pipe is a relative new product, which has been on the market for approximately twenty years. During the past several years, the use of aluminized corrugated steel pipe has increased in Charleston County, and its' use has been approved by the Charleston County Public Works Department. Based upon studies by Armco.Steel with asphalt coating, it is as good as paved invert galvanized steel pipe. Aluminized corrugated steel pipe with asphalt coating is an acceptable alternative to RCP, provided the pipe has the minimum gage thickness and sufficient cover as provided for in Table P-3.

h. Plastic Coated Steel Pipe is manufactured by several different companies with each product being slightly different. Plastic coated steel pipe is fairly new on the market; however, the Colorado Highway Department has studied the pipe and reports the following:

Nexon Coated Metal manufactured by U.S. Steel. After three years of installation in a corrosive environment the coatings were beginning to come off, and in the areas where the coatings were detached, the pipes were rusting. In a separate study conducted by the Colorado Highway Department, the report stated: "Coupons prepared using this material performed quite well except for those exposed to combinations of salts in water. Some loss of adhesion and blistering was evident, however." Based on the above and due to the lack of experience with this material, it is recommended that this type of pipe be utilized only on an experimental basis in areas where replacement is inexpensive.

Plasticote manufactured by Wheeling Steel. After a year's time in Colorado the pipe was in good condition;

however, this was not sufficient time to evaluate its performance. The plasticote utilized in Colorado was ten mils thick on the outside and 3 mils thick on the inside. Approximately seven years ago, the Charleston County Public Works Department allowed some plasticote pipe to be installed on an experimental basis at Quail Run Subdivision, on James Island where it empties directly into a tidal marsh and is subjected to tidal influences. At this installation the plasticote pipe is three mils thick on the outside and ten mils thick on the inside. An on-site examination of the pipe revealed the following:

1. The pipe appeared to be in better condition than plain asphalt coated corrugated metal pipe as evidenced by field observation of both types. The pipes were installed simultaneously within 150 feet of each other with both encountering approximately the same type conditions.

2. The outside coating of the pipe needs to be thicker than the three mils utilized for this pipe to help prevent damage during installation and blistering from the sunlight.

3. The plasticote pipe has a better appearance in areas where it is exposed than the asphalt coated pipe.

Based on the above, it is recommended that this type of pipe be utilized as an alternate to plain asphalt coated pipe with the same minimum gage and cover requirements, provided it is coated with a 12 mil thickness of plasticote on the inside and 10 mil thickness of plasticote on the outside. In addition, plasticote pipe can be used as an alternate to asphalt coated asbestos bonded steel in areas where replacement is inexpensive.

<u>Blac-Clad manufactured by Inland Steel</u>. The only independent testing that could be found on this type of pipe was with the Colorado Highway Department. After four years in Colorado there were no visible signs of corrosive attack on this pipe. Due to the lack of experience in this area, it is recommended that it be used only on an experimental basis in areas where replacement will be very inexpensive until further information is made available concerning this type pipe.

<u>Kinkote Plastic Coating manufactured by Kenitex Corporation</u>. This type plastic coating can be utilized on both steel and aluminum pipe. According to the results of testing conducted by the Colorado Highway Department, it performed better than any of the other plastic coatings on both the steel and aluminum pipes.

Based on the Colorado Highway Department's findings, it is recommended that Kinkote Plastic Coating be utilized as an alternate to fully asphalt coated steel and be utilized on aluminum pipe in areas which are very corrosive, such as tidal storm drains. It is not recommended that this type pipe be utilized as culverts or storm sewers on major streets and highways until further information is made available concerning its life expectancy.

i. Aluminum Corrugated Metal Pipe was introduced in the late 1950's and information concerning its ability to hold up through the years is just becoming available. Reports from the 1960's (Washington State and New York State) found aluminum pipe to be satisfactory; however, these conclusions were based on only three or four years experience with the material. Both of these reports suggested that bituminous coatings were unnecessary except in unusually harsh conditions, since "the outside cladding material is provided as a scarificial protection similar to galvanizing on steel." Later reports (Colorado Report, 1977) as well as the manufacturers' representatives, say the asphalt coating is unnecessary; and according to the manufacturers, the asphalt coating will not adhere to the aluminum. There are some reports of aluminum pipe suffering from severe corrosion due to tidal action, and this was also a problem which was noted in the Washington State Study. For this reason it is recommended that aluminum pipes which are subjected to tidal influences and which are used as culverts under major streets or highways, or otherwise expensive to replace, be coated with a material such as Kinkote manufactured by the Kenitex Corporation which will adhere to aluminum. (See Plastic Coated Pipe.)

Aluminum's lightweight and long laying lengths give it an advantage over reinforced concrete pipe and the equivalent, fully asphalt coated paved invert corrugated steel pipe. Due to its lighter weight, the pipe gives up much of its structural strength in the smaller gages and has a tendency to be crushed during installation as evidenced by the Colorado State report which found "contractors to be hesitant to use aluminum for fear of damage in transit or installation."

They suggested that aluminum culverts could be used where light equipment is required, such as rest areas and bike paths."

Based on the above, it is recommended that aluminum pipe be used with the gages shown in Table P-4, "Minimum Gage Sizes for Corrugated Aluminum Pipe," with the minimum cover requirements noted for secondary streets and highways or with the minimum cover requirements as noted for primary streets and highways and closed systems as applicable and provided the equivalent reinforced concrete pipe diameters found in Table P-2 are used. It should be noted that aluminum pipe is not acceptable for use by the American Railway Engineering Association, and therefore, cannot be used under railroads except on an experimental basis.

V. RECOMMENDATION

It is recommended that the City of Charleston specify reinforced concrete pipe with O-ring gaskets and accept corrugated metal pipe equivalents as shown in this report as being acceptable alternates.

VI. TABLES

The following Tables should be used for design calculations of storm sewers and culverts.

TABLE P-1

REINFORCED CONCRETE PIPE CLASSIFICATIONS[1]

Pipe Diameter	Maximum Depth of Cover Top of Pipe to Top of Ground in Feet[3]		
	Class III	Class IV	Class V[4][5]
12"	9.5	13.5	19.0
15"	9.5	13.5	20.0
18"	9.5	13.5	20.0
21"	10.0	14.0	21.0
24"	10.0	14.0	21.0
27"	10.5	14.5	22.0
30"	10.5	15.0	22.0
36"	10.5	15.0	23.0
42"	11.0	16.0	23.0
48"	11.5	16.0	23.0
54"	11.5	16.5	23.5
60"	12.0	17.0	23.5
66"	12.0	17.0	23.5
72"	12.5	17.0	23.5
78"[2]	12.5	17.0	24.0

NOTES:

1. Classifications based on ASTM Specification C76, Latest Revision.
2. Larger diameter pipes shall be considered on an individual basis.
3. Depth of cover based on Wall Thickness B.
4. Pipes which require greater cover shall be considered on an individual basis.

TABLE P-2

Equivalent Pipe Diameters
for
Reinforced Concrete and Corrugated Metal Pipe

Pipe Diameter Reinforced Concrete[1]	Equivalent Pipe Diameter Corrugated Metal Helical[2]	Annular[3]
12"	15"	15"
15"	18"	18"
18"	21"	24"
21"	24"	27"
24"	30"	30"
30"	36"	36"
36"	42"	48"
42"	48"	54"
48"	54"	60"
54"	60"	66"
60"	72"	72"
66"	78"	78"
72"[4]	84"	90"

NOTES:

1. A Mannings n of 0.015 was used for reinforced concrete pipe.
2. A Mannings n of 0.021 was used for helical corrugated metal pipe.
3. A Mannings n of 0.024 was used for annular corrugated metal pipe.
4. Larger diameter pipes shall be considered on an individual basis.

TABLE P-3

MINIMUM WALL GAGE THICKNESS
FOR
CORRUGATED STEEL PIPE[1]

Pipe Size	Minimum Cover		2-2/3"x1/2" Corrugations	3"x1" Corrugations
12"	12"[2]	12"[3]	16 ga.	-
15"	12"	12"	16 ga.	-
18"	12"	12"	16 ga.	-
21"	12"	12"	14 ga.	-
24"	12"	12"	14 ga.	-
27"	12"	12"	14 ga.	-
30"	12"	12"	14 ga.	-
36"	12"	12"	14 ga.	16 ga.
42"	12"	12"	12 ga.	14 ga.
48"	12"	12"	12 ga.	14 ga.
54"	12"	18"	10 ga.	12 ga.
60"	12"	18"	10 ga.	12 ga.
66"	12"	18"	12 ga.	12 ga.
72"	12"	18"	8 ga.	10 ga.
78"	12"	24"	8 ga.	10 ga.
84"	12"	24"	8 ga.	10 ga.
90"	12"	24"	8 ga.	10 ga.
96"[4]	12"	24"	8 ga.	10 ga.

NOTES:

1. Pipe gage thickness recommendation is based on the Handbook of Steel Drainage and Highway Construction Products concerning structural design together with information on the effects of deterioration on the thickness design of corrugated metal pipe.
2. Minimum cover of corrugated steel pipe based on H-20 highway loading.
3. Minimum cover of corrugated steel pipe based on E-80 railroad loading.
4. Larger diameter pipes shall be considered on an individual basis.

TABLE P-4

MINIMUM WALL GAGE THICKNESS
FOR
CORRUGATED ALUMINUM PIPE[1]

Pipe Size	Minimum Cover Type "A"	Minimum Cover Type "B"[3]	2-2/3"x1/2" Corrugations	3"x1" Corrugations
12"	2'-0"	1'-0"	14 ga.	-
15"	2'-0"	1'-0"	14 ga.	-
18"	2'-0"	1'-0"	12 ga.	-
21"	2'-0"	1'-0"	12 ga.	-
24"	2'-0"	1'-0"	12 ga.	-
27"	2'-0"	1'-0"	10 ga.	-
30"	2'-0"	1'-0"	10 ga.	10 ga.
36"	2'-0" or 3'-0"[4]	1'-0"	10 ga.	10 ga.
42"	3'-0"	1'-0"	10 ga.	10 ga.
48"	3'-0"	1'-0"	8 ga.	10 ga.
54"	3'-0"	1'-3" or 1'-6"[5]	8 ga.	8 ga.
60"	3'-0"	1'-3"	-	8 ga.
66"	3'-0"	1'-6"	-	8 ga.
72"	3'-0" or 4'-0"[6]	1'-6"	-	8 ga.
78"	4'-0"	1'-6" or 1'-9"[7]	-	8 ga.
84"	4'-0"	1'-6" or 1'-9"[7]	-	8 ga.
90"	4'-0"	1'-9"	-	8 ga.
96"[9]	4'-0"	1'-9" or 2'-0"[8]	-	8 ga.
17"x13"	2'-0"	1'-0"	14 ga.	-
21"x15"	2'-0"	1'-0"	14 ga.	-
24"x18"	2'-0"	1'-0"	14 ga.	-
28"x20"	2'-0"	1'-0"	12 ga.	-
35"x24"	2'-0"	1'-0"	12 ga.	-
42"x29"	2'-6"	1'-3"	10 ga.	-
49"x33"	2'-6"	1'-3"	10 ga.	-
57"x38"	2'-6"	1'-3"	8 ga.	-
64"x43"	3'-0"	1'-6"	8 ga.	-
71"x47"[9]	3'-0"	1'-6"	8 ga.	-

NOTES:

1. Pipe wall gage thicknesses recommended based on past experience and recommendations of the manufacturers' brochures.

2. Type "A" minimum cover based on H-20 loading plus installation loading for primary streets and roads as well as closed drainage systems.

3. Type "B" minimum cover based on H-20 loading only for secondary streets and highways.

4. 3'-0" of cover required for 2-2/3"x1/2" corrugation and 2'-0" of cover required for 3"x1" corrugations.

5. 1'-6" of cover required for 2-2/3"x1/2" corrugations and 1'-3" of cover required for 3"x1" or 6"x1" corrugations.

6. 3'-0" of cover required for 3"x1" corrugations and 4'-0" of cover required for 6"x1" corrugations.

7. 1'-6" of cover required for 3"x1" corrugations and 1'-9" of cover required for 6"x1" corrugations.

8. 1'-9" of cover required for 3"x1" corrugations and 2'-0" of cover required for 6"x1" corrugations.

9. Larger diameter pipes shall be considered on an individual basis.

APPENDIX C

SOIL CHARACTERISTICS

CITY OF CHARLESTON

MASTER DRAINAGE AND FLOODPLAIN MANAGEMENT PLAN

APPENDIX C

SOIL CHARACTERISTICS

I. GENERAL

The soil associations within the present City of Charleston area as delineated by Soil Survey of Charleston County, South Carolina, USDA, Soil Conservation Service and Forest Service, in cooperation with the South Carolina Agricultural Experiment Station, dated March 1971, are shown in Figures 17 thru 20. The numbers on this map represent the various soil associations which were used on the General Soil map which is part of the above referenced Soil Survey.

There are six established soil association areas within the Charleston city limits in addition to the peninsular area. Table 1 lists these six areas, the percentage of the total city land area which each comprises, and other data which are pertinent to this study. The general characteristics of each soil association pertinent to this report are summarized below:

3. Chipley-Lakeland Association

This association occurs in the northern part of the peninsular area and accounts for approximately 5 percent of the study area. The soils of this association are moderately to well drained fine sands, which become coarser as the depth below the surface layer increases. Runoff generated from this association is low.

5. Wando-Seabrook Association

This association occurs within the James Island portion of the study area and accounts for approximately 10 percent of the soils within the study area. The soil is a fine loamy sand which is typically well to excessively drained. Amounts of runoff generated from this association tends to be low.

6. Kiawah-Seabrook-Dawhoo Association

This association occurs within the Johns Island portion of the study area. The soils are typically sandy and are generally well drained, dependent upon the existing water table height. Runoff generated from this association tends to be low.

7. Yonges-Hockley-Edisto Association

This association occurs in the West of the Ashley area and is the largest soil association within the study area, accounting for approximately 30 percent of the total area. The association is a moderately well drained to poorly drained soil that has a sandy surface layer and a predominately loamy subsoil. The water table is typically 24 to 36 inches below the surface area. Rate of runoff generated from this association tends to be high.

10. Tidal Marsh Association

This association occurs within all portions of the study area and comprises approximately 20 percent of the total area. The soil is a soft loam, clay, muck, or peat which is covered by 6 to 24 inches of water at high tide and is constantly wet. Construction within this area is regulated by the South Carolina Coastal Council and the U.S. Army Corps of Engineers. Due to the absence of building in this soil association, the amount of runoff generated is not significant.

11. Mine, Pits, Dumps, Made Land

This association makes up 10 percent of the study area, and consist mainly of old phosphate mining areas. The land is characterized by high, narrow ridges, with water-filled troughs between the ridges. The majority of this area is wooded and the amount of runoff generated is very low.

The area which comprises the peninsular area of the City of Charleston was not included in the survey. As far as can be determined, there is no existing formal documentation of the soil characteristics of the peninsular area. However, from a basis of general knowledge of the historical development of the tidal marsh and other soil areas in this location, it is logical to assume that the general characteristics of these soils are comparable to those in the contiguous areas within the city limits.

Soil characteristics of primary significance in Table 1 are the Reaction (pH value) and the Composite Hydrological Group Association. The Reaction is an indication of the degree of acidity or alkalinity of each soil series, and is expressed in numerical form in Table 1. A soil having a pH of less than 7 is classified as acidic and those having a pH greater than 7 are alkaline.

The Composite Hydrological Group Association classifies the soil groups according to their infiltration and water transmission rates. This association is utilized in Technical Release No. 55, "Urban Hydrology for Small Watersheds" by USDA, Soil Conservation Service to estimate the amount of runoff from a given watershed. The Hydrologic Soil Groups are listed in Table 2.

The climate for the area is temperate with heavy, well distributed rainfall. A large portion of the study area is also effected by tidal action. Table 1 shows a high incidence of soils with hydrological characteristics which primarily tend to hold moisture. Due to these influences, the area soils remain predominately moist throughout most of the year.

II. CONCLUSIONS

From the data given in Table 1 it is evident that a predominate characteristic of the soil in the City of Charleston area is its moderately acidic nature. The acidic condition combined with the presence of moisture results in soils which have a low resistivity value. The resistivity of a soil is a measure of the soils ability to resist the process of electrolysis. The presence of soils with low resistivity, combined with the acidic nature of the soil lead conclusively to the fact that the soil environment of the study area is predominately aggressively corrosive.

The corrosive environment is even greater for those areas which are subject to tidal action due to the cylical presence of the salt water and the residual salinity of the soil in these areas.

TABLE 1

CHARLESTON AREA SOIL CHARACTERISTICS

SOIL ASSOCIATION	% LAND AREA	SOIL SERIES	% EXTENT (WITHIN ASSOCIATION)	REACTION (pH)	HYDROLOGICAL GROUP (EACH SERIES)	COMPOSITE HYDROLOGICAL GROUP ASSOCIATION	
						GROUP	% EXTENT
3- Chipley-Lakeland	5	Chipley	66	5.1/5.5	A	A	88%
		Lakeland	23	4.5/5.5	A		
		Rutledge		5.1/5.5	B	B	12%
		Osier	11	4.5/5.0	A		
		Wagram		5.1/5.5	A		
5- Wando-Seabrook	10	Wando	51	6.1/6.5	A	A	55%
		Seabrook	31	5.1/6.0	C	B	30%
		Kiawah		5.1/6.0	B	C	15%
		Rutledge		5.1/5.5	B		
		Dawhoo	18	6.1/6.5	B		
		Charleston		4.5/5.5	D		
		Wagram		5.1/5.5	A		
		Edisto		4.5/5.5	C		
6- Kiawah-Seabrook-Dawhoo	10	Kiawah	48	5.1/6.0	B	B	70%
		Seabrook	19	5.1/6.0	C	C	30%
		Dawhoo	17	6.1/6.5	B		
		Rutledge		4.5/5.0	B		
		Wando	16	6.1/6.5	A		
		Edisto		4.5/5.1	C		
		Yonges		4.5/8.4	D		
7- Yonges-Hockley-Edisto	30	Yonges	31	5.6/8.4	D		
		Hockley	21	4.5/5.5	B	B	28%
		Edisto	14	4.5/5.5	C	C	14%
		Charleston		4.5/5.5	D	D	58%
		Meggett		4.5/7.3	D		
		Santee	34	5.1/6.5	D		
		Wadmalaw		4.5/8.4	D		
		Wicksburg		4.5/6.5	B		
10- Tidal Marsh	20	Tidal Marsh	70	4.5/7.0	D	A	18%
		Capers	18	5.6/6.5	D		
		Coastal Beaches		5.6/6.0	A		
		Dune Land		5.6/6.0	A	D	82%
		Crevasse	12	5.1/5.5	A		
		Dawhoo		6.5/6.5	B		
		Pamlico		4.5/6.0	D		
		Rutledge		5.1/5.5	B		
11- Mine Pits, Dumps, Made Land	10	Pits & Dumps (Old Phosphate Mines)	70		D	D	100%
		Made Land	30				
Peninsula	15	(See Text)				A	70%
						C	30%

TABLE 2

HYDROLOGIC SOIL GROUPS

The soils of the study area have been classified into four hydrologic soil groups. The hydrologic soil groups, according to their infiltration and transmission rates, are:

A. (Low runoff potential). Soils having high infiltration rates even when thoroughly wetted. These consist chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission in that water readily passes through them.

B. Soils having moderate infiltration rates when thoroughly wetted. These consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Soils having slow infiltration rates when thoroughly wetted. These consist chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D. (High runoff potential). Soils having very slow infiltration rates when thoroughly wetted. These consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

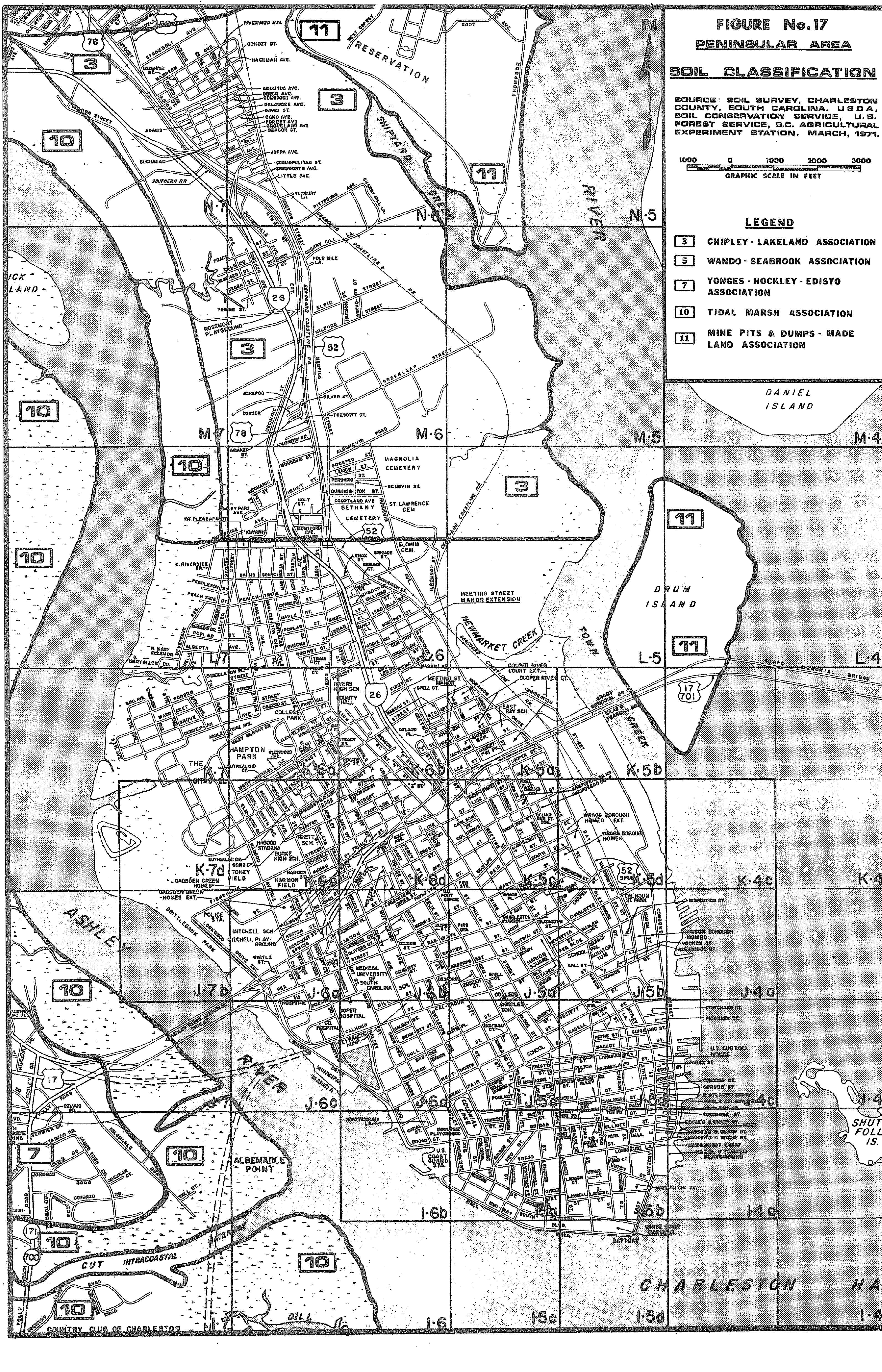
FIGURE No.17
PENINSULAR AREA
SOIL CLASSIFICATION
SOURCE: SOIL SURVEY, CHARLESTON COUNTY, SOUTH CAROLINA. USDA, SOIL CONSERVATION SERVICE, U.S. FOREST SERVICE, S.C. AGRICULTURAL EXPERIMENT STATION. MARCH, 1971.
1000 0 1000 2000 3000
GRAPHIC SCALE IN FEET
LEGEND
3 CHIPLEY - LAKELAND ASSOCIATION
5 WANDO - SEABROOK ASSOCIATION
7 YONGES - HOCKLEY - EDISTO ASSOCIATION
10 TIDAL MARSH ASSOCIATION
11 MINE PITS & DUMPS - MADE LAND ASSOCIATION
N
DANIEL ISLAND
DRUM ISLAND
SHUTE FOLL IS.
ALBEMARLE POINT
ASHLEY RIVER
RIVER
SHIPYARD CREEK
RESERVATION
NEWMARKET CREEK
TOWN CREEK
CHARLESTON HA
INTRACOASTAL WATERWAY
CUT
COUNTRY CLUB OF CHARLESTON
HAMPTON PARK
THE CITADEL
COLLEGE PARK
MAGNOLIA CEMETERY
ST. LAWRENCE CEM.
BETHANY CEMETERY
ELOHIM CEM.
ROSEMONT PLAYGROUND
MEETING STREET MANOR EXTENSION
MEDICAL UNIVERSITY OF SOUTH CAROLINA
U.S. COAST GUARD STA.
U.S. CUSTOM HOUSE
WHITE POINT GARDENS
BATTERY
N·7 N·6 N·5
M·7 M·6 M·5 M·4
L·7 L·6 L·5 L·4
K·7 K·6a K·6b K·5a K·5b
K·7d K·6c K·6d K·5c K·5d K·4c K·4
J·7b J·6a J·6b J·5a J·5b J·4a
J·7 J·6c J·6d J·5c J·5d J·4c J·4
I·6b I·5b I·5a I·4a
I·6 I·5c I·5d I·4

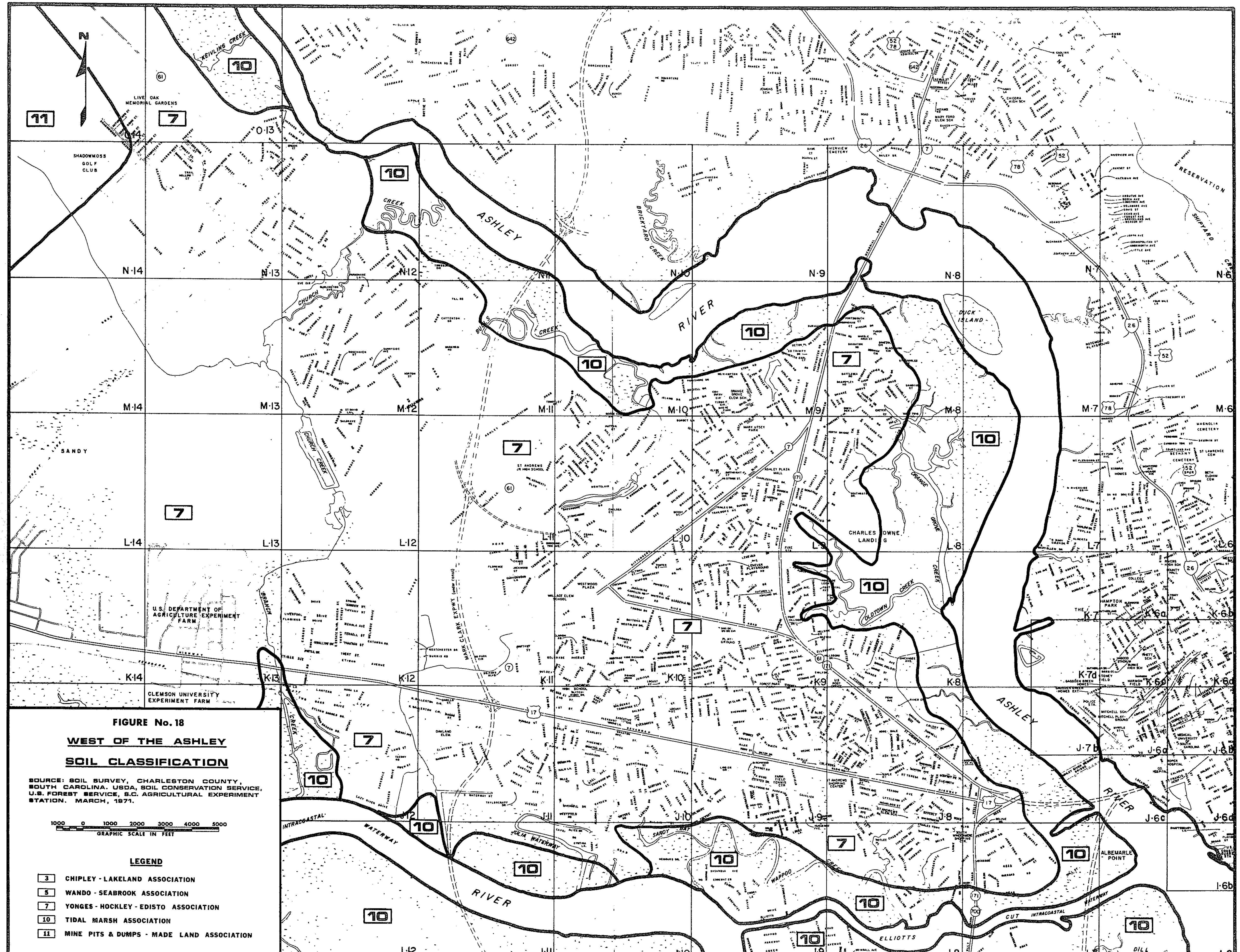
FIGURE No. 18
WEST OF THE ASHLEY
SOIL CLASSIFICATION
SOURCE: SOIL SURVEY, CHARLESTON COUNTY, SOUTH CAROLINA. USDA, SOIL CONSERVATION SERVICE, U.S. FOREST SERVICE, S.C. AGRICULTURAL EXPERIMENT STATION. MARCH, 1971.
1000 0 1000 2000 3000 4000 5000
GRAPHIC SCALE IN FEET
LEGEND
3 CHIPLEY - LAKELAND ASSOCIATION
5 WANDO - SEABROOK ASSOCIATION
7 YONGES - HOCKLEY - EDISTO ASSOCIATION
10 TIDAL MARSH ASSOCIATION
11 MINE PITS & DUMPS - MADE LAND ASSOCIATION
ASHLEY RIVER
WAPPOO CREEK
CHURCH CREEK
ELLIOTTS CUT
INTRACOASTAL WATERWAY
CHARLES TOWNE LANDING
DUCK ISLAND
ALBEMARLE POINT
U.S. DEPARTMENT OF AGRICULTURE EXPERIMENT FARM
CLEMSON UNIVERSITY EXPERIMENT FARM
SHADOWMOSS GOLF CLUB
LIVE OAK MEMORIAL GARDENS

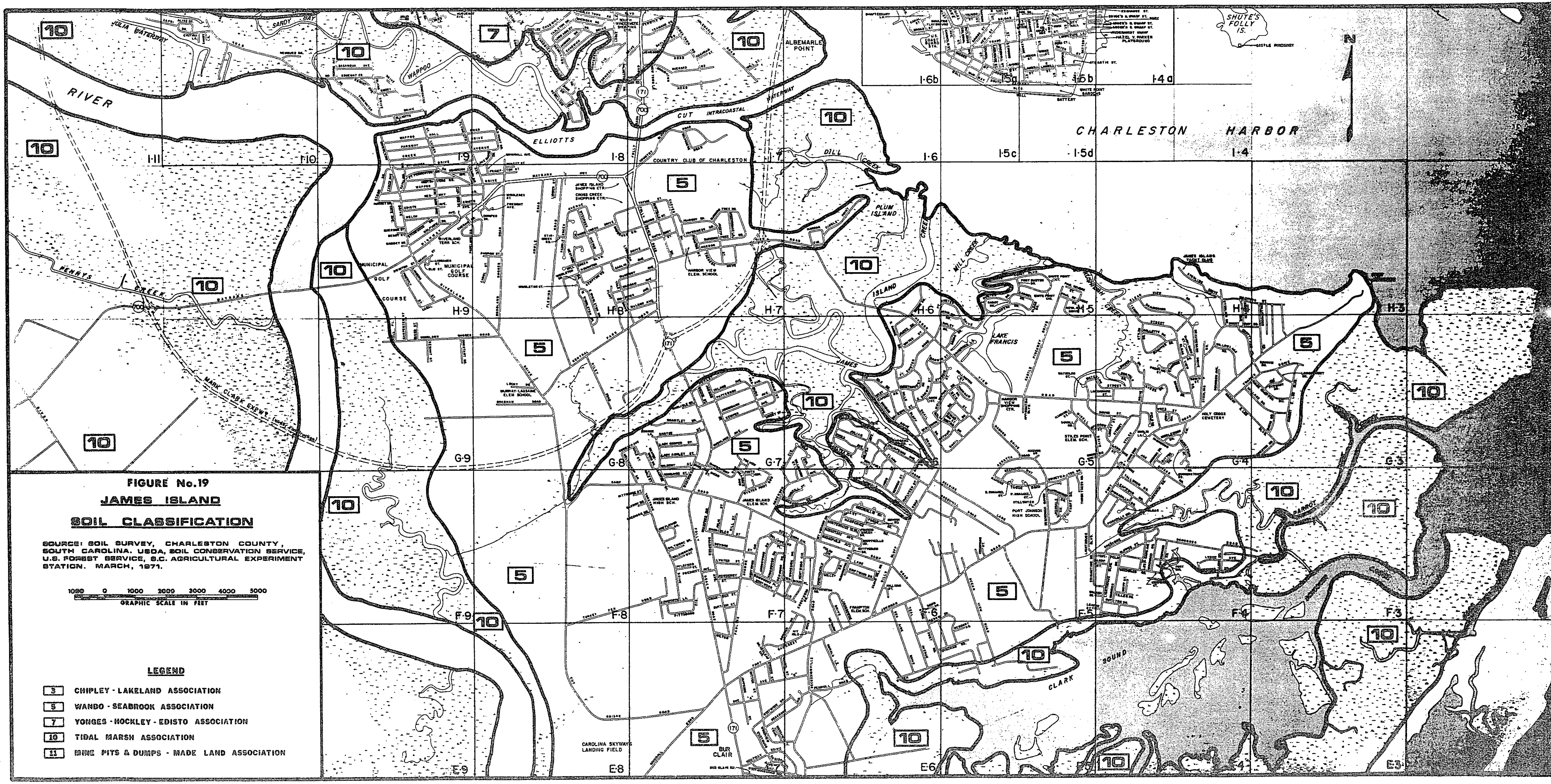

FIGURE No.19
JAMES ISLAND
SOIL CLASSIFICATION

SOURCE: SOIL SURVEY, CHARLESTON COUNTY, SOUTH CAROLINA. USDA, SOIL CONSERVATION SERVICE, U.S. FOREST SERVICE, S.C. AGRICULTURAL EXPERIMENT STATION. MARCH, 1971.

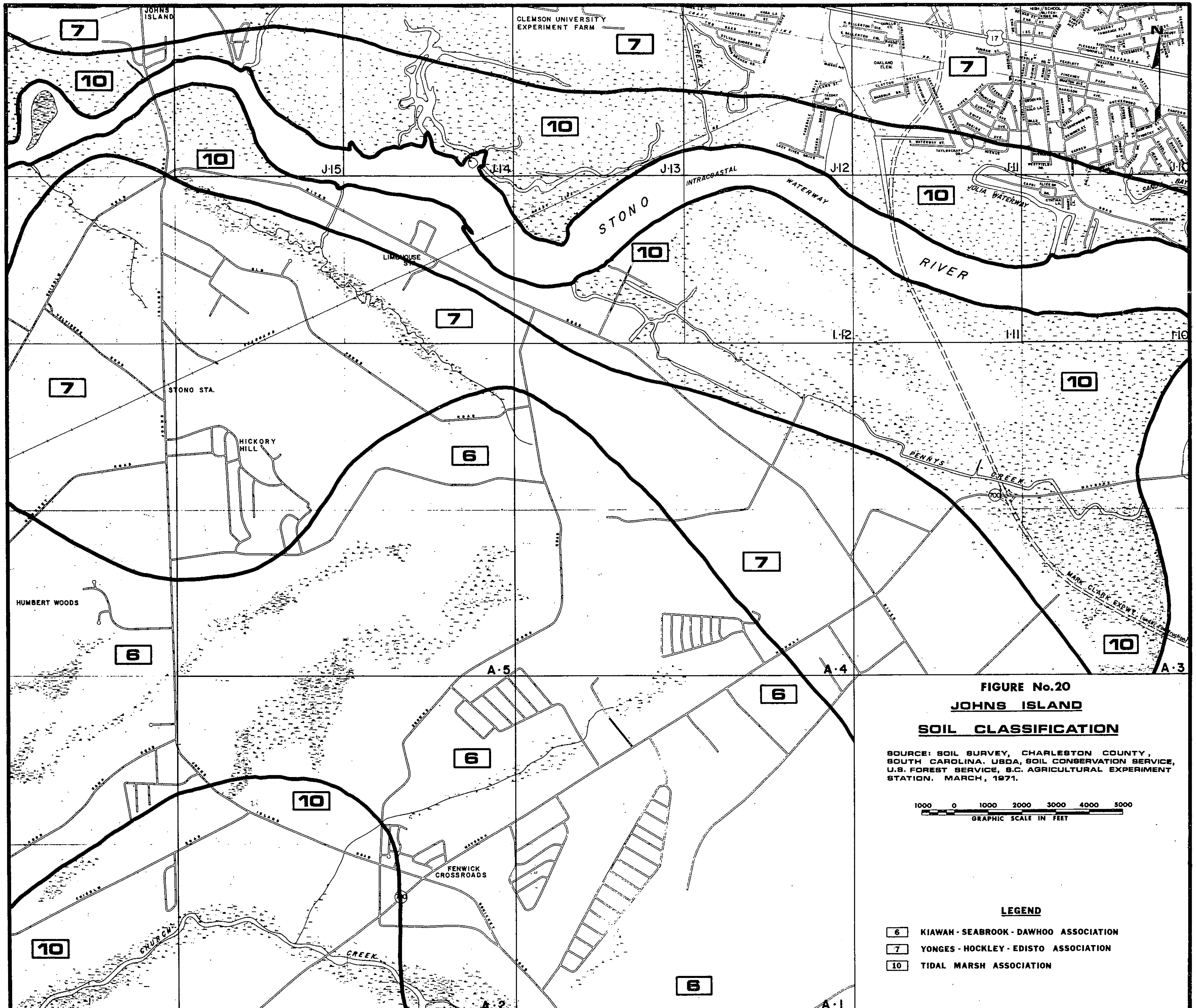

FIGURE No. 20

JOHNS ISLAND

SOIL CLASSIFICATION

SOURCE: SOIL SURVEY, CHARLESTON COUNTY, SOUTH CAROLINA. USDA, SOIL CONSERVATION SERVICE, U.S. FOREST SERVICE, S.C. AGRICULTURAL EXPERIMENT STATION. MARCH, 1971.

1000 0 1000 2000 3000 4000 5000
GRAPHIC SCALE IN FEET

LEGEND

6 KIAWAH - SEABROOK - DAWHOO ASSOCIATION
7 YONGES - HOCKLEY - EDISTO ASSOCIATION
10 TIDAL MARSH ASSOCIATION