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APPLICATION OF REMOTE SENSORS TO ARMY FACILITY MANAGEMENT; APPENDIX B: VALIDATION OF ENVIRONMENTAL MAPS PRODUCED THROUGH AIR-PHOTO INTERPRETATION

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Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

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APPLICATION OF REMOTE SENSORS TO ARMY FACILITY MANAGEMENT

APPENDIX B: VALIDATION OF ENVIRONMENTAL MAPS PRODUCED THROUGH AIR-PHOTO INTERPRETATION

by

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A study was performed to validate environmental baseline factor maps of the Fort Belvoir study area, which were prepared through air-photo interpretation without the aid of any supplementary data. A field data collection program was conducted to provide data to be compared with the information derived from the analysis of the aerial photos. It was found that the air-photo interpretation was quite accurate, but that increased accuracy would result if ground truth data were available to the interpreters during the interpretation process.

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Preface

The validation of environmental maps that were produced through air-photo interpretation is an extension of the study presented in the main report. Authorization for the work is contained in Intra-Army Order for Reimbursable Services dated 30 March 1972 from the Office, Chief of Engineers, to the U. S. Army Engineer Waterways Experiment Station (WES). The work was in support of Project 4A662707A890, "Extraterrestrial Research," for the Advanced Technology Branch, Engineering Division, Military Construction Directorate.

The study was conducted under the general supervision of Messrs. W. G. Shockley, Chief of the Mobility and Environmental Systems Laboratory (MESL), and W. E. Grabau, Chief of the Environmental Systems Division (ESD), MESL, and under the direct supervision of Mr. B. O. Benn, Chief of the Environmental Research Branch (ERB), ESD. This report was prepared by Messrs. J. H. Shamburger, Chief of the Terrestrial Sciences Branch, Engineering Geology Division (EGD), Soils and Pavements Laboratory, WES, and H. K. Woods (EGD).

Directors of WES during this program and the preparation and publication of this report were BG E. D. Peixotto, CE, and COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

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Contents

Conversion Factors, Metric (SI) to U. S. Customary and U. S. Customary to Metric (SI) Units of Measurement

Units of measurement used in this report can be converted as follows:

Multiply	By	To Obtain
	Metric (SI) to U. S. Customary	
meters	3.2808	feet
square meters	10.76	square feet
centimeters	0.3937	inches
micrometers	3.2808×10^{-3}	feet
	U. S. Customary to Metric (SI)	
feet	0.3048	meters
square miles	2.59	square kilometers

APPENDIX B: VALIDATION OF ENVIRONMENTAL MAPS PRODUCED THROUGH AIR-PHOTO INTERPRETATION

Background

1. The study described in the main report was conducted to determine the feasibility of applying remote sensing techniques to Army needs for data in environmental monitoring, resource management, and master planning at multipurpose military installations in the contiguous United States. The environmental data requirements for these purposes were defined, and a general assessment was made of the applicability of current photographic, thermal infrared, and microwave imaging systems to obtain these data. Aerial photographic techniques were found to be the ones most generally applicable to acquisition of data relevant to basic environmental conditions.

2. Prototype products consisting of maps of basic environmental conditions, cultural features, and land use were produced from aerial photography of Fort Belvoir, Virginia, and a surrounding area. The maps were prepared to demonstrate the feasibility of using remote sensing techniques to produce an environmental baseline for a multipurpose military installation and to detect changes in environmental conditions over specific time periods.

Purpose and Scope

3. As recommended in the main report, the purpose of the study described in this appendix was to validate the baseline factor maps of the Fort Belvoir study area, which were prepared through air-photo interpretation without the aid of any supplementary data. The baseline factors (and their class ranges) are listed in Table B1. A field program was conducted to measure and/or observe the mapped factors. The results were then compared with the data derived from air-photo

interpretations. The study was accomplished in the following phases: (a) site selection, (b) data collection, (c) data reduction and analysis, (d) map revision, and (e) evaluation of the air-photo interpretation. Work performed during these phases is discussed in the following paragraphs.

Site Selection

4. In this study an efficient sampling program is defined as one that includes only the number of sites necessary to verify the physical characteristics that have resulted in specific air-photo patterns. Therefore, before sites were selected for the field program reported herein, the imagery obtained in the initial study was examined for distinctive patterns identified during the mapping. A desired sample density within each pattern and map unit had to be determined, so several sites within each pattern were selected to avoid one set of data representing the same pattern throughout the study area. Sites whose characteristics were uncertain during the air-photo interpretation study were automatically included as sites to be visited.

5. Eighty-six sites were selected, 50 reconnaissance and 36 sample. Reconnaissance sites were those on which visual observations were made and noted on a topographic map or aerial mosaic. (An aerial mosaic of Fort Belvoir is presented in Plate B1.) Sample sites (Plate B2) were those on which physical measurements were made and recorded on field data forms.

Data Collection

6. Data were collected during 5-11 September 1973. Although a particular site may have been selected to verify one baseline factor, in many instances, other baseline factors occurred at the site and were also sampled. This adventitious sampling increased the data available, without a significant increase in the time required to perform the field data collection process.

Vegetation type

7. A visual inspection was made to identify the vegetation type (deciduous, coniferous, mixed, crops, grasses, or aquatic weeds). The first three types required additional sampling in terms of area occupancy. For an area to be identified as coniferous, 75 percent or more of it had to be occupied by conifers. If neither deciduous nor coniferous types occupied 75 percent or more of an area, it was placed in the mixed class. The field sampling was accomplished by establishing a site of known dimensions and then determining the occupancy of tree types within the sample area based on the number of plants of each type.

Vegetation height

8. Measurement of variation within the height classes was restricted to the deciduous, coniferous, and mixed classes; the remaining classes fell within the ≤2-m* range and required only reconnaissance-type sampling. In vegetation types where heights of >2 m occurred, height was measured with a Haga altimeter. Sample sites were established within an area where 20 stems occurred within a height class. The sites were spaced, as required, to verify the mapping.

Vegetation density

9. A site was laid out that occupied a known area (a multiple of 100 m^2). After the limits of the site were established, the number of stems occurring within the limits was counted, and the site was placed in the appropriate factor class.

Wildlife habitat

10. The sampling criteria for the classes of this factor are based principally on topographic position and salt content of the water. Verification or sampling of the uplands and bottomlands was accomplished through reconnaissance, not by any field measurement method. This reconnaissance did not identify any changes to make to the original map. The salt content of the water in the marsh areas is a dynamic condition depending on the amount of freshwater inflow of the streams and the tidal

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* A table of factors for converting metric (SI) units of measurement to U. S. customary units, and U. S. customary units to metric (SI) units, is given on page B4.

cycle of the Potomac River nearby. These conditions usually result in a transition zone and not a sharp break between brackish and fresh water. Therefore, no attempt was made to sample the water salinity in the marshes near the junction of the small streams with the Potomac River. Also, no errors were found in the delineations of the uplands and bottomlands; therefore, there was no need to revise the map. However, the map derived through air-photo interpretation is included in this appendix to maintain the numbering sequence established in the main report.

Soil type

11. Soil type was determined through a visual analysis of road cuts, streambanks, and other exposed areas, and by sampling the top 20 cm of soil with a hand shovel for classification according to the Unified Soil Classification System (USCS).

Depth to bedrock

12. Depth to bedrock was determined by examining road cuts, streambanks, exposed slopes, etc. The height of exposure and the presence or absence of rock were noted. No rock outcrops were found; however, large boulders were located in the floodplain of a stream in the western part of the study area; these had not been identified by photo interpretation.

Surface water

13. Streams and other drainage channels were checked to determine whether they were accurately identified or had been omitted. During this reconnaissance, areas were also checked for the possible occurrence of springs (none were found). Areas mapped as lakes and ponds were also visited to verify the interpretations.

Depth to groundwater

14. No subsurface exploration was performed to determine the depth to groundwater. This type of investigation is beyond the scope of the study, and published data were relied upon to check the mapping. The original map was not revised, but it is included for continuity, as stated in paragraph 10.

Pollution sources

15. The reconnaissance made for this factor included visits to

gravel pits, training sites, filtration plants, highways, etc. The original map was not revised, but it is included for continuity.

Cultural features and land use

16. Although not specifically included in this study, some of the cultural and land-use factors were checked, and appropriate notations were made for comparison with the mapped classes; for example, the class of roads as indicated on a topographic map was checked and then used to verify the photo interpretation. Most of this type of sampling required only a reconnaissance through the area followed by making the appropriate annotations.

Natural resources

17. This baseline factor is a combination of several of the above-discussed factors and was not sampled per se.

Data Reduction and Analysis

18. The sample site data collected were reduced, as required, and tabulated. Quantitative values or descriptive terms for each baseline factor were identified on the tabulations in terms of a factor class (Table B1). The field data are presented in Table B2. Where reconnaissance data were collected, the pertinent annotations were made on the appropriate factor map. The location of each sample site where data were collected for a specific factor was plotted on the appropriate factor map or overlay, and the factor class was designated at the location.

19. In the analysis phase, the values on the original map for each factor were compared with the values obtained during the fieldwork. This was a systematic process of placing the overlay, on which field data were plotted, over the original factor map. Outlined areas identified by classes on the original maps were compared with the classes identified from the fieldwork to determine the variations between the two. This process was continued until all the factors had been compared. It should be pointed out that during the fieldwork an inspection was made to see whether the on-site values or descriptions agreed

with mapped ones. Where disagreement occurred that was greater than the range of a factor class, the air photos were used to establish tentatively the position of the revised boundary. The new boundary line was then field-checked to determine its validity. If it did not check, the procedure above was repeated until a valid boundary could be drawn.

Map Revision

20. The original maps were revised where variations occurred between them and the overlays that were prepared from the field data. These variations resulted in separate overlays for each factor map, except those for wildlife habitat, depth to groundwater, and pollution, and are shown in Plates B1ar-B1cr, B1er-B1gr, and B1jr-B1ℓr. The original maps (with revisions if necessary) are presented as Plates B1a-B1c, B1e-B1g, and B1j-B1ℓ. The changes were of three types: (a) line shifting, (b) change of factor class, and (c) addition of new areas. In general, the original mapped units were altered very slightly, with a few exceptions, and a few baseline factor maps required no alterations (Plates B1d, B1h, and B1i). Some specific changes are described below.

Vegetation type (Plates B1a and B1ar)

21. The three predominant types--deciduous, coniferous, and mixed--are easily identified within the study area from the aerial photos. One small area of conifers was added in the northeast portion of the military reservation, and the limits were revised for one area of deciduous vegetation and for one area where vegetation was absent.

Vegetation height (Plates B1b and B1br)

22. The major changes in heights occurred in the northeast and southwest portions of the study area. As in the changes in vegetation type, these portions of the area were small in number and areal extent.

Vegetation density (Plates B1c and B1cr)

23. Minor alterations were made in the northeast and southwest portions of the study area.

Wildlife habitat (Plate B1d)

24. No revisions were made for this factor.

Soil type (Plates B1e and B1er)

25. The major drainageways were originally mapped as clay (CL) but were revised to show that they contain silty sand (SM) and silty gravel (GM), as well as clay. The boundary of silty gravel was adjusted slightly in the vicinity of the cantonment area of Fort Belvoir. Gravel is more abundant and widespread on the surface than was inferred from the aerial photos. Soils along the lower end of Accotink Creek were revised to include more clay. Two areas of clayey sand (SC) were added south of the present construction site of the Engineer Topographic Laboratories and the Kingman Building.

Depth to bedrock (Plates B1f and B1fr)

26. The area north of Pohick Estates and north of Interstate 95 was changed from $\leq$1 m to >1-3 m.

Surface water (Plates B1g and B1gr)

27. Swimming pools were removed from the original map, and a pond was added in the Pohick State Park south of Jefferson Davis Highway.

Depth to groundwater and pollution (Plates B1h and B1i)

28. No revisions were made for these factors.

Cultural features (Plates B1j and B1jr)

29. The major revisions consisted of upgrading or downgrading small segments of unsurfaced roads or two-lane, hard-surfaced roads.

Land use (Plates B1k and B1kr)

30. The presence of sanitary fills was added to the original map. The area of Pohick State Park was revised to show that it is recreational. A few training areas, administrative buildings, and troop and family housing were altered.

Natural resources (Plates B1ℓ and B1ℓr)

31. This map is a compilation of pertinent data from the vegetation height, soil, depth to bedrock, and surface water maps. Therefore, those revisions that were required on the appropriate maps formed the changes to the natural resources map. The revisions of this factor resulted from the changes indicated on the soil and vegetation height maps.

Evaluation of Air-Photo Interpretations

32. To evaluate the air-photo interpretations, the revisions or changes to the maps discussed in the preceding paragraphs were studied. The revisions involved shifting lines, changing classes (either in outlined areas or roads that are identified by lines), omitting lines, and adding lines. The revised factor maps were compared visually with the original maps, the changes that were made were evaluated, and the percentage of the interpretation that was correctly made was determined for each original map. This procedure was performed by three individuals, who estimated the accuracy. The average of these results formed the basis for final percentage values presented in Table B3. If these values are averaged, the result is a 94 percent overall accuracy.

33. It should be noted that the evaluation is subjective, but it is felt that the results are realistic and reflect the proper accuracy of the air-photo interpretation. A more rigorous evaluation of the maps might change the percentage values slightly, but it was assumed that the additional accuracy of the evaluation would not be worth the cost of establishing and implementing a comprehensive evaluation scheme. Indeed, a thorough evaluation of air-photo interpretation would require systematic consideration of many more film-filter combinations, mission profiles, alternative ways of getting the desired information, costs, etc., than the scope of this study permitted. However, the practice of using remote sensing devices is increasing in almost every discipline that requires data from the physical environment. This increase can be contributed to advancements in the acquisition of remote imagery. For example, remote sensing was initially restricted to cameras and films that sensed only the visible portion of the electromagnetic spectrum in tones of gray. Since World War II, advancements include the introduction of black-and-white films that are capable of sensing the environment in the near-infrared portion of the electromagnetic spectrum up to wavelengths of 1 μm and of color films that increase the sensing of natural and false colors. The natural-color films intensify the definition of objects that are difficult or impossible to detect in shades

of gray. False-color films allow the determination of conditions that are not detectable on other types of film.

34. The development of scanning sensors has expanded the capability of sensing in the ultraviolet, middle, and far-infrared wavelengths and in the radar wavelengths of the electromagnetic spectrum. Far-infrared sensing has made possible the determination of temperature differential during day or night. Radar scanners can be used to sense at night and in adverse weather conditions that are beyond the capability of other systems. The introduction of multispectral sensors (both scanning and cameras) is another step in increasing the ability to sense specific wavelength ranges in the electromagnetic spectrum. This has enhanced the identification of things that emit or reflect energy within narrow wavelength ranges. The earth-orbiting satellites have produced synoptic views of the earth surface covering up to 10,000 square miles and can repeatedly cover the area of interest. Advances have been, and are being, made to increase the quality of the remote sensing product through better cameras, sharper lenses, faster and finer-grain film, and filters that minimize solar effects. Scanners have advanced to the point of producing images on film (under certain conditions) of specific subjects of near-photographic quality.

35. Techniques of analyzing imagery have also improved. Electronic sensing devices are available to measure and digitize photographic tones for pattern recognition analyses. Techniques are also available in which an image is mathematically enhanced and reprinted so that more detail can be seen by a human interpreter.

36. Remote sensing should be considered only one of several means of obtaining information for planning, monitoring, and managing resources. For this reason, the decision to use remote sensing products should be made on a cost-effective basis. The acquisition of remote sensing products is normally obtained through a contractor; however, considerable acquisition capability is owned by the Government, and often these resources can be exploited. The cost for contracting remote imagery coverage varies considerably and is dependent upon several parameters including area, geographic location, type of terrain, type(s) of

sensors, film and film processing, sidelap and overlap, type of aircraft, etc. A contractor also includes in his bid aircraft ferrying cost, standby time at his base of operations, mobilization and demobilization (including mission planning and crew expense), and any groundwork that has to be accomplished. The only way to obtain an accurate cost is to determine the project requirements and advertise for bids. However, to obtain an idea of the costs experienced for completed projects, a brief search in the literature was made and conversations with representatives of Government agencies were held. The results of this survey revealed, as expected, that prices vary considerably even for the same type of coverages. Costs were expressed in terms of per square mile, linear mile, and flight hour. Project requirements included different types of sensors, scanners, and cameras (with varying focal lengths and film sizes) and final products (prints and transparencies). These data were reviewed and a generalized cost per square mile for obtaining imagery was determined, as shown in the following tabulation:

Type	Altitude ft	Scale	Cost/square mile, dollars
Panchromatic and black-and-white IR (infrared)	15,000-20,000	1:30,000-1:40,000	2.00-4.50
Panchromatic and black-and-white IR	7,500-10,000	1:15,000-1:20,000	3.00-7.50
Color	15,000-20,000	1:30,000-1:40,000	3.50-10.00
IR scanner	10,000	--	4.75-10.00
Radar	Unknown	--	4.75-7.00
Multispectral camera	16,000	--	30.00

37. It should be kept in mind, however, that the cost of getting the remote sensing products is only part of the data-gathering expense. As stated in the main report, the successful use of remote sensing systems almost always implies that the following six sequential processes have been carried out:

a. Problem specification (what is the problem; what kinds of information are needed to solve it; and can a remote sensing system obtain any or all of the needed information).

b. Acquisition of ground control data (determination of how things of interest are related on the ground in selected locations, to serve as a basis for interpreting those relations over the entire time and region of interest).

c. Data acquisition with a remote sensing system (the actual process of sensing and recording data in the region of interest at the time of interest).

d. Data manipulation (putting the information obtained by the remote sensing system into a form suitable for analysis and/or interpretation).

e. Information extraction (actually performing the analysis and/or manipulation to obtain the needed data from the product of the remote sensing system).

f. Information presentation (putting the extracted data into a form that can be used to assist in solving the problem at hand).

38. Although the cost for using the remote sensing products may far exceed the cost of product acquisition, experience at the U. S. Army Engineer Waterways Experiment Station has led to the conclusion that it is extremely effective from a cost standpoint to use remote sensing products in data acquisition when data are desired on an areal basis.

Conclusions

39. The study reported herein demonstrated the value of using remote imagery as a tool for reliable data acquisition (see paragraph 32). The reliability of the final product can be improved through the use of ground truth data in the image interpretation process. The effectiveness of field data collection to support air-photo interpretation can be increased significantly by careful selection of the field data collection sites. The location and number of sampling points should be selected by study of the air photos prior to execution of the field data collection program (see paragraph 4).

Vegetation Type		Vegetation Height		Vegetation Density		Wildlife Habitat			
Map Class	Description	Map Class	Height Range, m	Map Class	Stems/100 m^2	Map Class	Description	Map Class	USCS Symbo
1	Deciduous woodland ≥75%	1	≤2	1	≤8	1	Upland	1	GW
2	Coniferous woodland ≥75%	2	>2-4	2	>8-32	2	Bottomland	2	GP
3	Mixed forest	3	>4-8	3	>32-128	3	Freshwater marsh	3	GM
4	Crops	4	>8	4	>128	4	Brackish marsh	4	GC
5	Grasses	5	Not identified	5	Not identified	5	Salt marsh	5	SW
6	Aquatic weeds							6	SP
7	Absent							7	SM
								8	SC
								9	ML
								10	MH
								11	CL
								12	CH
								13	OL
								14	OH
								15	PT

Table B1

Factors and Factor Classes Mapped

Soil Type			Depth to Bedrock		Surface Water		Depth to Groundwater		Pollution Sour	
s	USCS Symbol	Description	Map Class	Depth Range, m	Map Class	Description	Map Class	Depth Range, m	Map Class	Descri
	GW	Gravel, well graded	1	≤1	1	Lakes and ponds	1	≤2	1	Gases disper
	GP	Gravel, poorly graded	2	>1-3	2	Rivers and streams	2	>2	2	Solids disper
	GM	Silty gravel	3	>3	3	Springs and geysers			3	Gases and sol persed in
	GC	Clayey gravel							4	Chemicals di water
	SW	Sand, well graded							5	Organics dis water
	SP	Sand, poorly graded							6	Chemicals an dispersed
	SM	Silty sand							7	Chemicals di on land
	SC	Clayey sand							8	Organics dis land
	ML	Inorganic silts, clayey silts							9	Chemicals an dispersed
	MH	Elastic silts							10	Noise
	CL	Low-to-medium plastic clays, sandy or gravelly clays								
	CH	Highly plastic clays								
	OL	Organic clays or silts, low plasticity								
	OH	Organic clay, medium-to-high plasticity								
	PT	Peat and other highly organic soils								

Pollution Sources	
	Description
	ases dispersed in air
	olids dispersed in air
	ases and solids dis- persed in air
	hemicals dispersed in water
	rganics dispersed in water
	hemicals and organics dispersed in water
	hemicals dispersed on land
	rganics dispersed on land
	hemicals and organics dispersed on land
	oise

Cultural Features	
Map Class	Description
1	Buildings
2	Airports
3	Roads, 4-lane, hard-surfaced
4	Roads, 2-lane, hard-surfaced
4a	Roads, 3-lane, hard-surfaced
5	Roads, unsurfaced
6	Railroads, single-track
7	Railroads, multiple-track
8	Navigation canals
9	Abandoned railways

Land Use	
Map Class	Description
1	Deciduous woodland
2	Coniferous woodland
3	Mixed woodland
4	Scrub
5	Grassland
6	Crops
7	Orchard and vineyards
8	Industrial
9	Commercial
10	Institutional and religious
11	Governmental complex (undifferentiated)
	a. Training areas
	b. Administrative buildings and areas
	c. Troop housing
	d. Family housing
	e. Open storage
	f. Covered storage
	g. Pollution control
	h. Airfield
	i. Utilities
	j. Sanitary fill
12	Residential
13	Recreational
14	Mining and quarrying
15	Marshland

Natural Resources	
Map Class	Description
1	Clay, <2 m overburden
2	Sand, <2 m overburden
3	Gravel, <2 m overburden
4	Bedrock, <2 m overburden
5	Timber, ≥8 m in height
6	Surface water
7	Absent

Table B2

Environmental Data Collected at Sample Sites

Site No.	Military Grid Coordinate	Vegetation Type		Vegetation Height, m		Vegetation Density Stems/100 m^2		Wildlife Habitat		Soil Type		
		Class	Description	Class	Description	Class	Description	Class	Description	Class	USCS Symbol	Dep Clas
1	11378286	1	Deciduous	4	>8	1	≤8	1	Upland	3	GM	3
2	11008239	3	Mixed	4	>8	4	>128	1	Upland	7	SM	NS*
3	08968272	2	Coniferous	3	>4-8	3	>32-128	1	Upland	7	SM	NS
4	08328328	2	Coniferous	4	>8	3	>32-128	1	Upland	7	SM	NS
5	08258336	1	Deciduous	4	>8	1	≤8	1	Upland	7	SM	NS
6	08948450	1	Deciduous	4	>8	1	≤8	2	Bottomland	13	OL	3
7	09538479	7	Absent	NA		NA		1	Upland	3	GM	3
8	10528583	1	Deciduous	4	>8	4	>128	1	Upland	7	SM	NS
9	11728621	1	Deciduous	4	>8	1	≤8	2	Bottomland	11	CL	NS
10	11728582	2	Coniferous	2	>2-4	2	>8-32	2	Bottomland	7	SM	NS
11	12468557	2	Coniferous	2	>2-4	3	>32-128	2	Bottomland	3	GM	NS
12	12558500	5	Grasses	1	≤2	4	>128	4	Brackish marsh	3	GM	3
13	13048492	1	Deciduous	4	>8	1	≤8	1	Upland	9	ML	NS
14	12918458	7	Absent	NA		NA		1	Upland	3	GM	3
15	13098448	1	Deciduous	4	>8	1	≤8	1	Upland	9	ML	NS
16	14758302	1	Deciduous	4	>8	1	≤8	1	Upland	3	GM	3
17	14738319	1	Deciduous	4	>8	1	≤8	1	Upland	9	ML	3
18	15278418	1	Deciduous	4	>8	1	≤8	1	Upland	3	GM	3
19	14628618	1	Deciduous	3	>4-8	3	>32-128	2	Bottomland	9	ML	NS
20	15968634	5	Grasses	1	≤2	4	>128	1	Upland	9	ML	NS
21	11378778	1	Deciduous	4	>8	1	≤8	1	Upland	7	SM	NS
22	12398833	2	Coniferous	4	>8	1	≤8	1	Upland	7	SM	NS
23	14508348	2	Coniferous	2	>2-4	4	>128	2	Bottomland	9	ML	NS
24	15328873	2	Coniferous	2	>2-4	3	>32-128	1	Upland	9	ML	NS
25	15288904	3	Mixed	4	>8	2	>8-32	1	Upland	9	ML	NS
26	15028923	3	Mixed	2	>2-4	3	>32-128	1	Upland	9	ML	NS
27	14248897	7	Absent	NA		NA		2	Bottomland	8	SC	NS
28	14398949	5	Grasses	1	≤2	1	≤8	2	Bottomland	9	ML	NS
29	14628970	1	Deciduous	4	>8	1	≤8	1	Upland	9	ML	NS
30	12658893	2	Coniferous	4	>8	2	>8-32	1	Upland	7	SM	NS
31	12718897	2	Coniferous	4	>8	2	>8-32	1	Upland	7	SM	NS
32	12248937	2	Coniferous	3	>4-8	2	>8-32	1	Upland	7	SM	NS
33	10688954	3	Mixed	4	>8	1	≤8	1	Upland	7	SM	NS
34	10479026	3	Mixed	4	>8	1	≤8	1	Upland	7	SM	NS
35	10989098	5	Grasses	1	≤2	1	≤8	1	Upland	7	SM	3
36	14089195	5	Grasses	1	≤2	4	>128	1	Upland	7	SM	NS

* Not applicable.
** Not sampled.

Table B2

Environmental Data Collected at Sample Sites

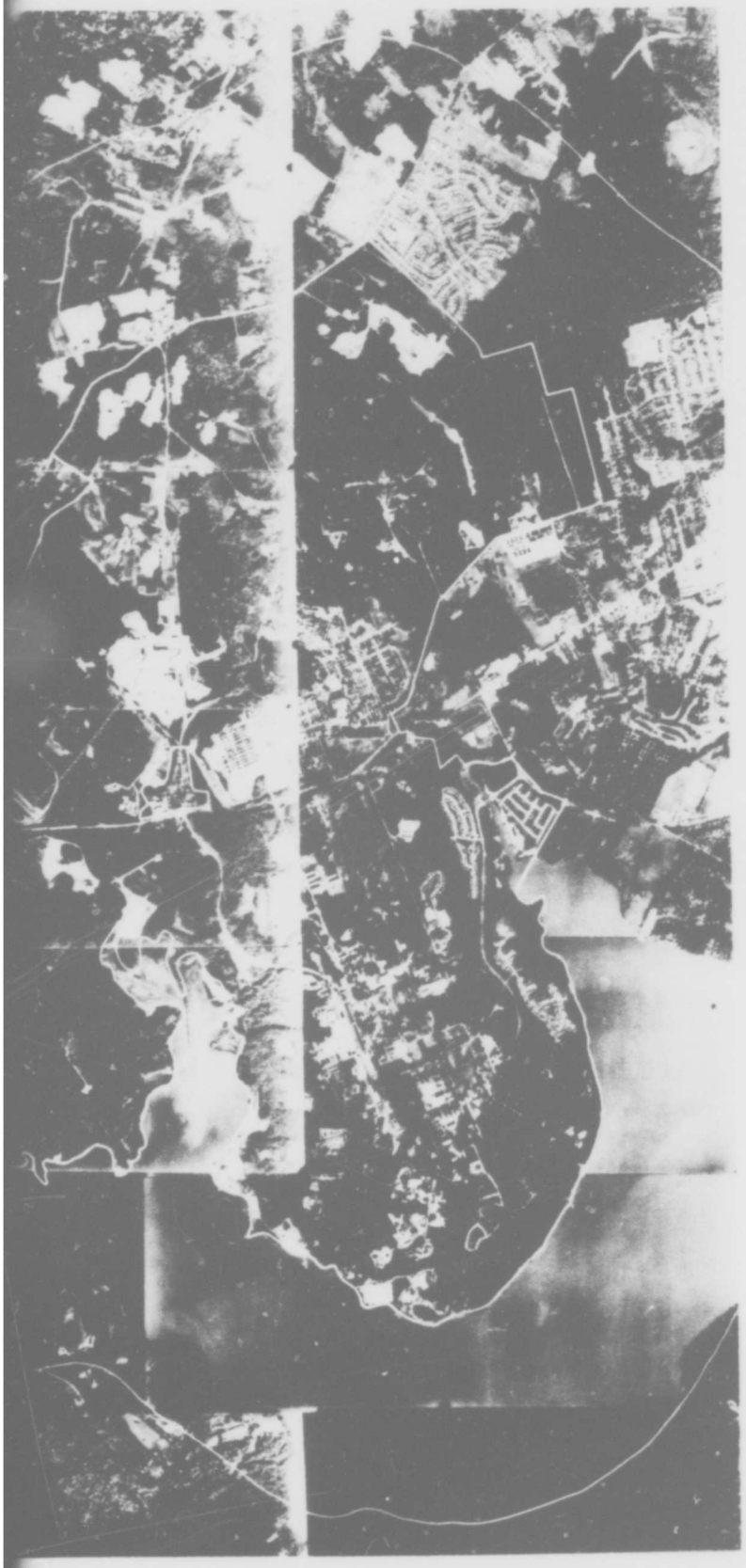
Vegetation Density Stems/100 m^2		Wildlife Habitat		Soil Type		Depth to Bedrock		Surface Water		Land Use	
Class	Description	Class	Description	Class	USCS Symbol	Class	Description	Class	Description	Class	Description
1	≤8	1	Upland	3	GM	3	>3 m	NA*		13	Recreational
4	>128	1	Upland	7	SM	NS**		NA		13	Recreational
3	>32-128	1	Upland	7	SM	NS		NA		2	Coniferous woodland
3	>32-128	1	Upland	7	SM	NS		NA		2	Coniferous woodland
1	≤8	1	Upland	7	SM	NS		NA		1	Deciduous woodland
1	≤8	2	Bottomland	13	OL	3	>3 m	2	Stream	15	Marshland
NA		1	Upland	3	GM	3	>3 m	NA		11a	Training area
4	>128	1	Upland	7	SM	NS		NA		11a	Training area
1	≤8	2	Bottomland	11	CL	NS		NA		1	Deciduous woodland
2	>8-32	2	Bottomland	7	SM	NS		NA		11j	Sanitary fill
3	>32-128	2	Bottomland	3	GM	NS		NA		2	Coniferous woodland
4	>128	4	Brackish marsh	3	GM	3	>3 m	2	River	15	Marshland
1	≤8	1	Upland	9	ML	NS		NA		11a	Training area
NA		1	Upland	3	GM	3	>3 m	NA		14	Quarry
1	≤8	1	Upland	9	ML	NS		NA		1	Deciduous woodland
1	≤8	1	Upland	3	GM	3	>3 m	NA		10	Institutional religious
1	≤8	1	Upland	9	ML	3	>3 m	NA		10	Institutional religious
1	≤8	1	Upland	3	GM	3	>3 m	NA		1	Deciduous woodland
3	>32-128	2	Bottomland	9	ML	NS		NA		1	Deciduous woodland
4	>128	1	Upland	9	ML	NS		NA		5	Grassland
1	≤8	1	Upland	7	SM	NS		NA		11a	Training area
1	≤8	1	Upland	7	SM	NS		NA		11a	Training area
4	>128	2	Bottomland	9	ML	NS		NA		11a	Training area
3	>32-128	1	Upland	9	ML	NS		NA		11a	Training area
2	>8-32	1	Upland	9	ML	NS		NA		11a	Training area
3	>32-128	1	Upland	9	ML	NS		NA		11a	Training area
NA		2	Bottomland	8	SC	NS		NA		11a	Training area
1	≤8	2	Bottomland	9	ML	NS		2	Stream	11g	Pollution control
1	≤8	1	Upland	9	ML	NS		NA		11a	Training area
2	>8-32	1	Upland	7	SM	NS		NA		11a	Training area
2	>8-32	1	Upland	7	SM	NS		NA		11a	Training area
2	>8-32	1	Upland	7	SM	NS		NA		13	Recreational
1	≤8	1	Upland	7	SM	NS		NA		12	Residential
1	≤8	1	Upland	7	SM	NS		NA		3	Mixed woodland
1	≤8	1	Upland	7	SM	3	>3 m	NA		5	Grassland
4	>128	1	Upland	7	SM	NS		NA		5	Grassland

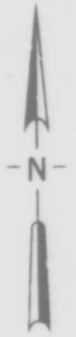
Table B3

Estimated Accuracy of Air-Photo Interpretation

Plate No.	Factor	Accuracy %
B1a	Vegetation type	99
B1b	Vegetation height	94
B1c	Vegetation density	96
B1d	Wildlife habitat	NE
B1e	Soil type	92
B1f	Depth to bedrock	98
B1g	Surface water	98
B1h	Depth to groundwater	NE
B1i	Pollution	NE
B1j	Cultural features	93
B1k	Land use	88
B1ℓ	Natural resources	94

Note: NE = Not evaluated.





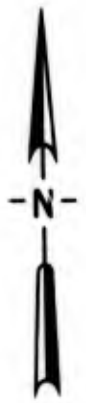
FORT BELVOIR 1972

AERIAL MOSAIC

20<

PLATE B1


ACCOTINK
POTOMAC RIV



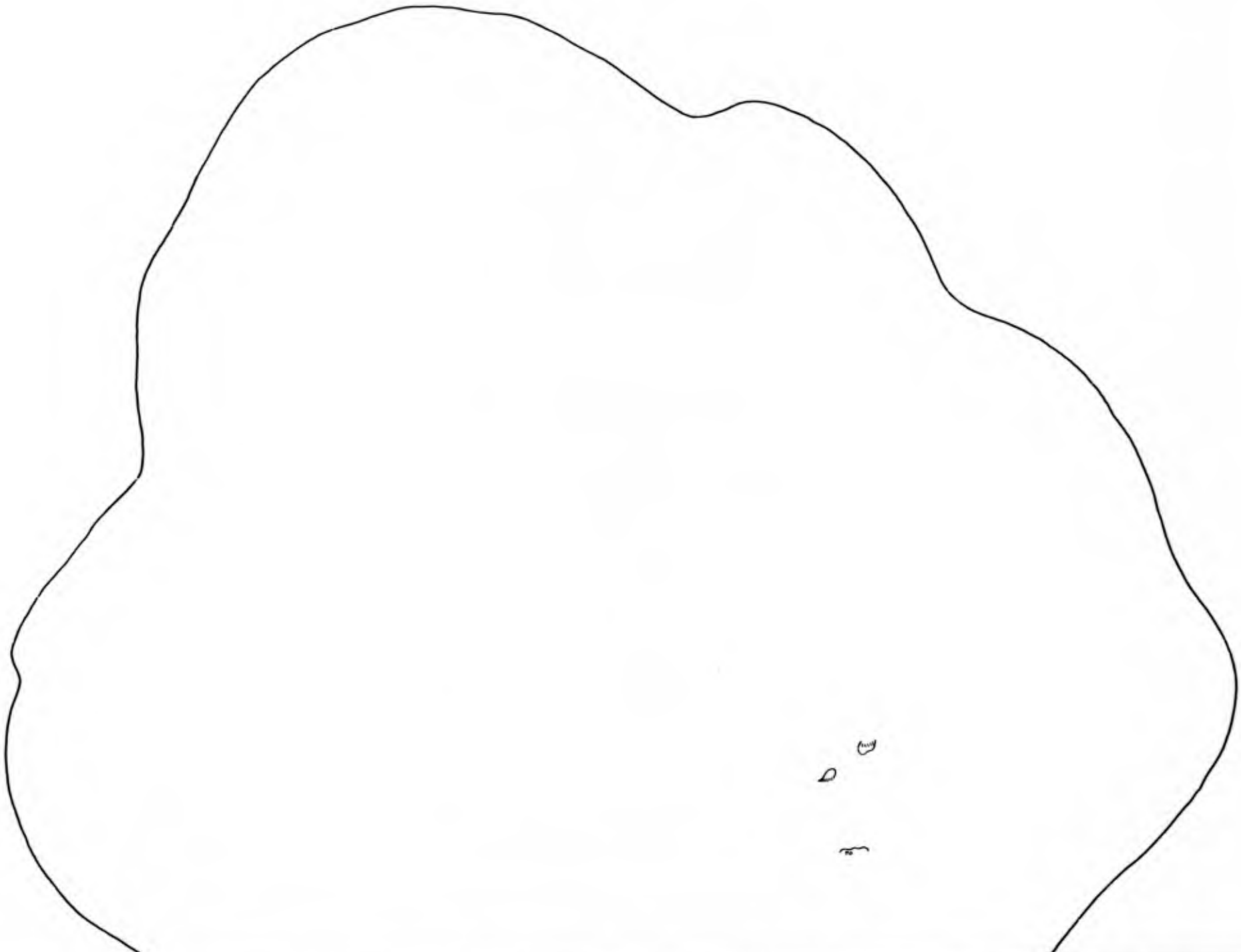
VEGETATION TYPE

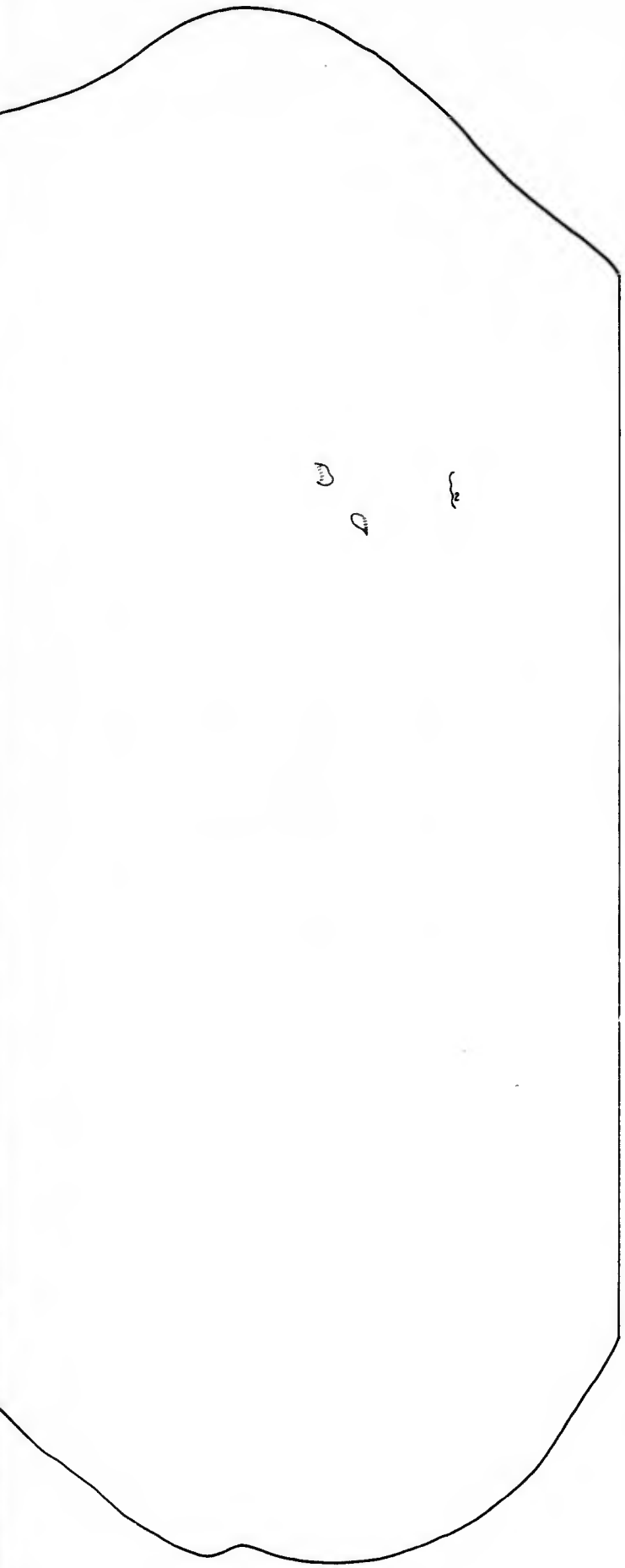
1. DECIDUOUS WOODLAND ≥75%
2. CONIFEROUS WOODLAND ≥75%
3. MIXED FOREST
4. CROPS
5. GRASSES
6. AQUATIC WEEDS
7. ABSENT

REVISED
FACTOR MAP, FORT BELVOIR 1972
VEGETATION TYPE

21<

PLATE B1 a





LEGEND

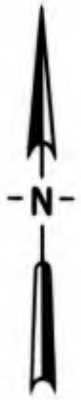
- REMOVE LINE
- 2 REMOVE NUMBER
- ADD LINE
- 3 ADD NUMBER

REVISIONS TO FACTOR MAP, FORT BELVOIR 1972

VEGETATION TYPE 22<

PLATE B1 ar


ACCOTINK
POTOMAC RIVER



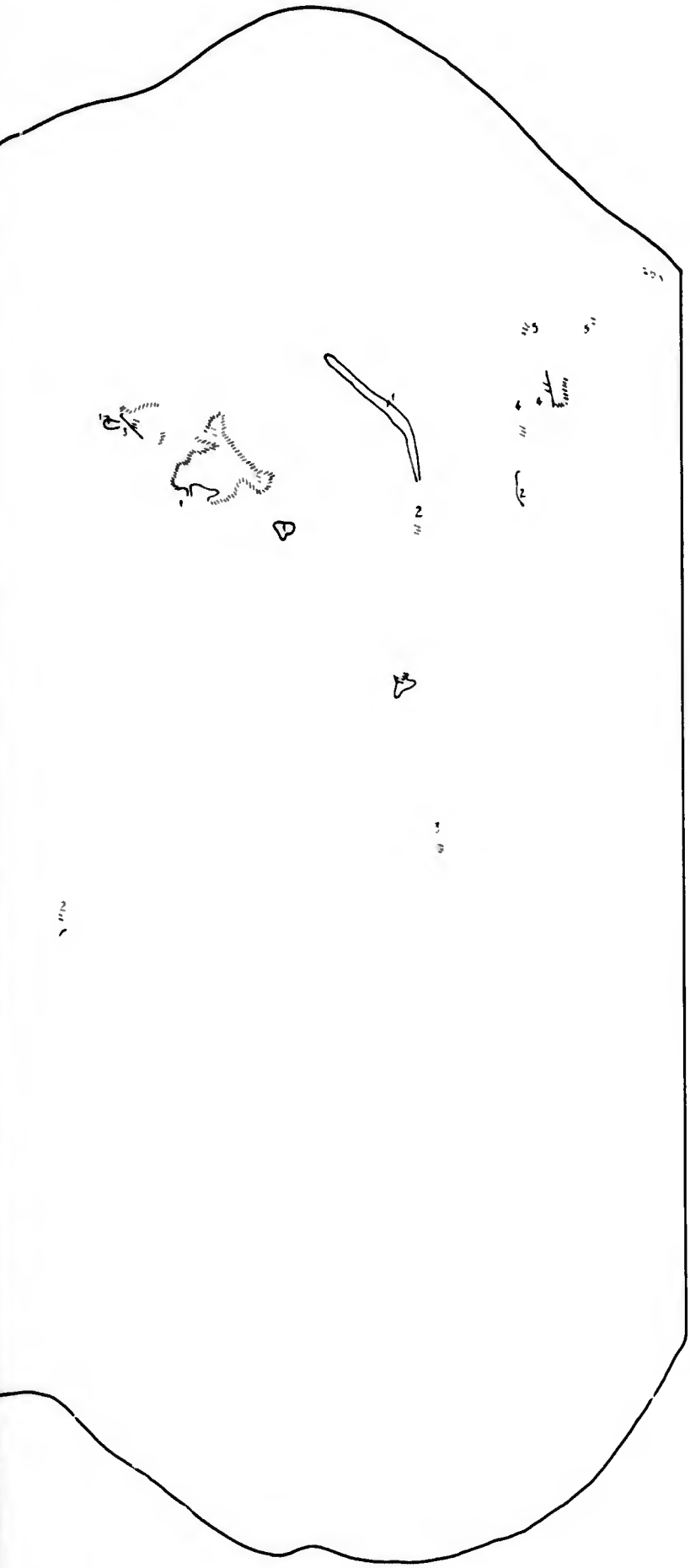
VEGETATION HEIGHT, METERS

1 <2
2 >2-4
3 >4-8
4 >8
5 NOT IDENTIFIED

REVISED
FACTOR MAP, FORT BELVOIR 1972
VEGETATION HEIGHT

23<

PLATE B1 b



LEGEND

REMOVE LINE

2 REMOVE NUMBER

ADD LINE

3 ADD NUMBER

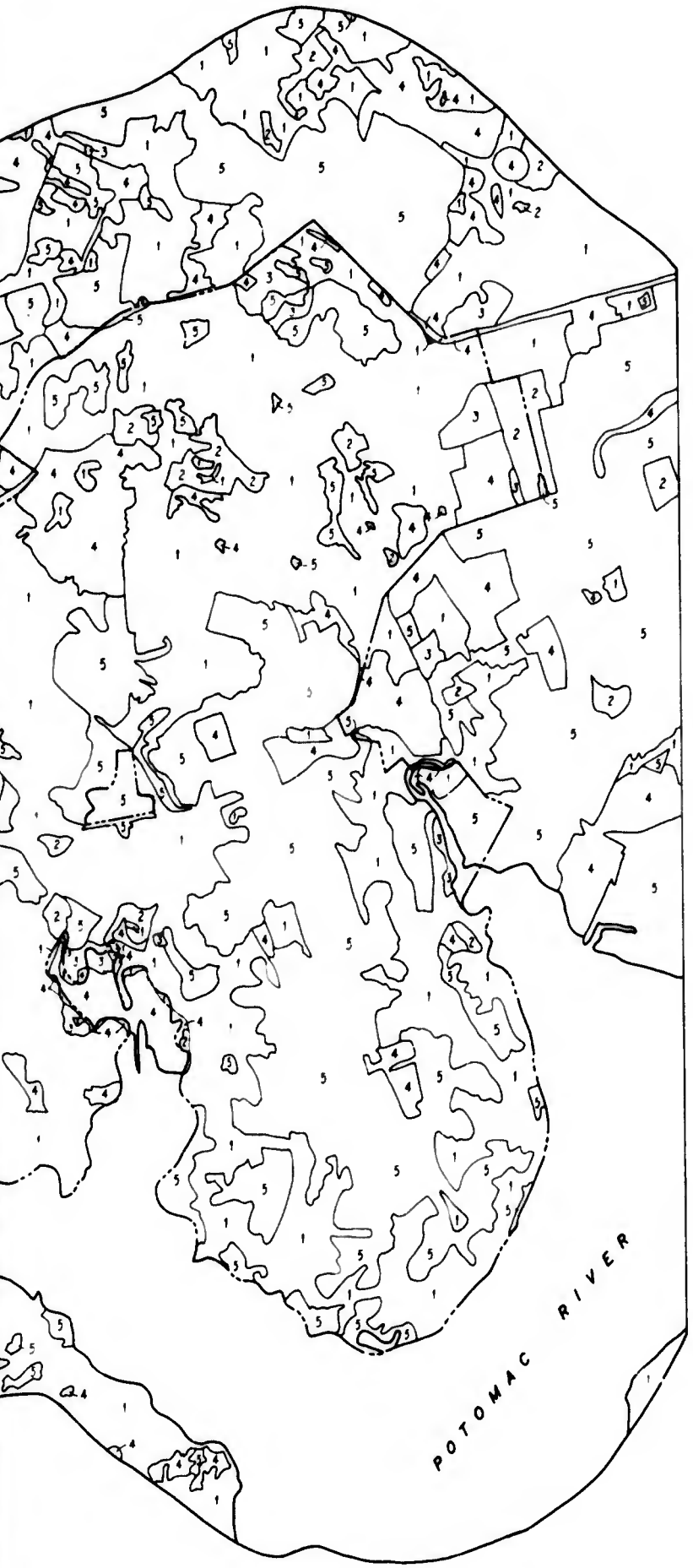
REVISIONS TO FACTOR MAP, FORT BELVOIR 1972

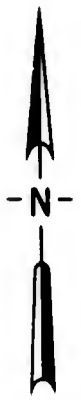
VEGETATION HEIGHT

24<

PLATE B1 br


POTOMAC RIV



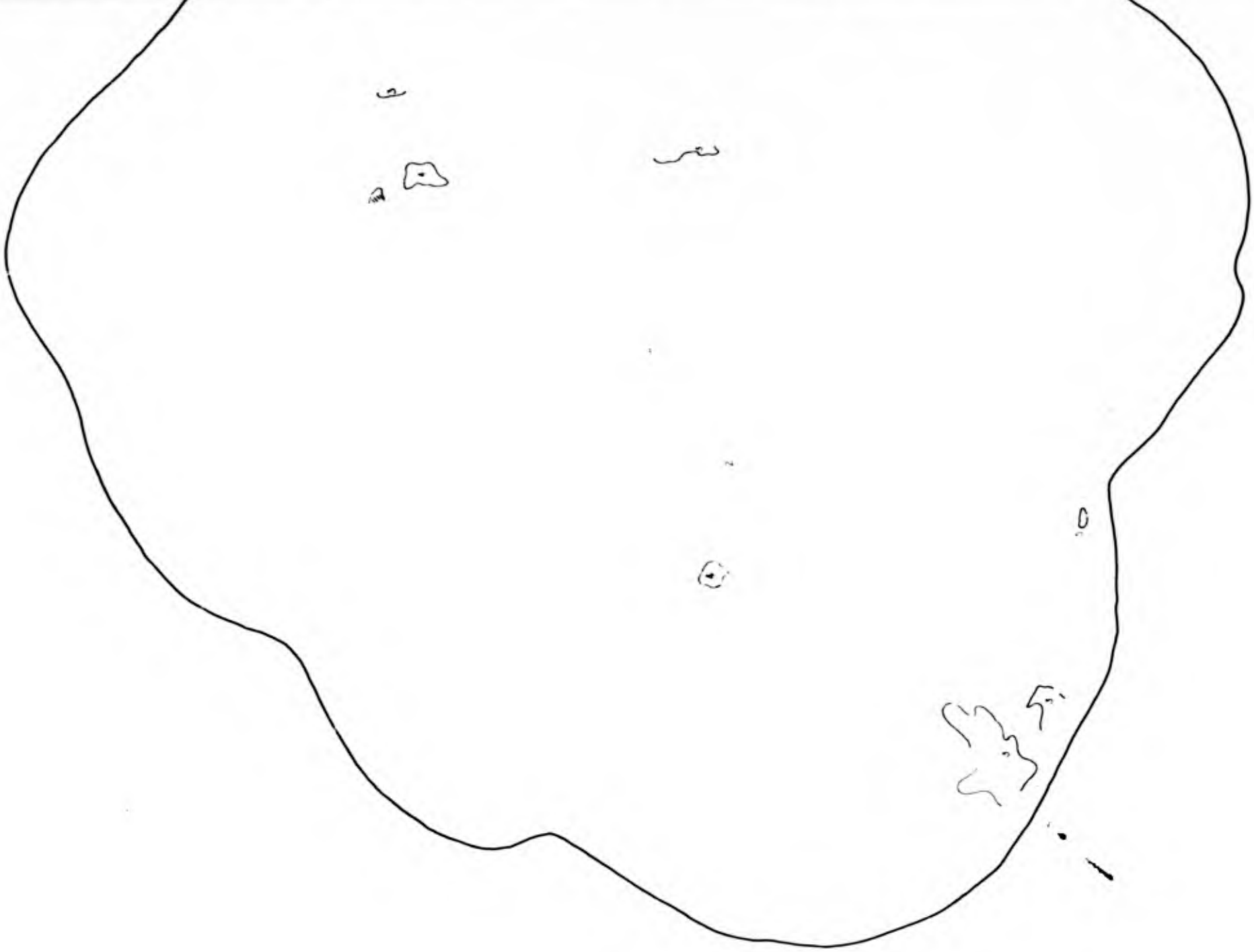


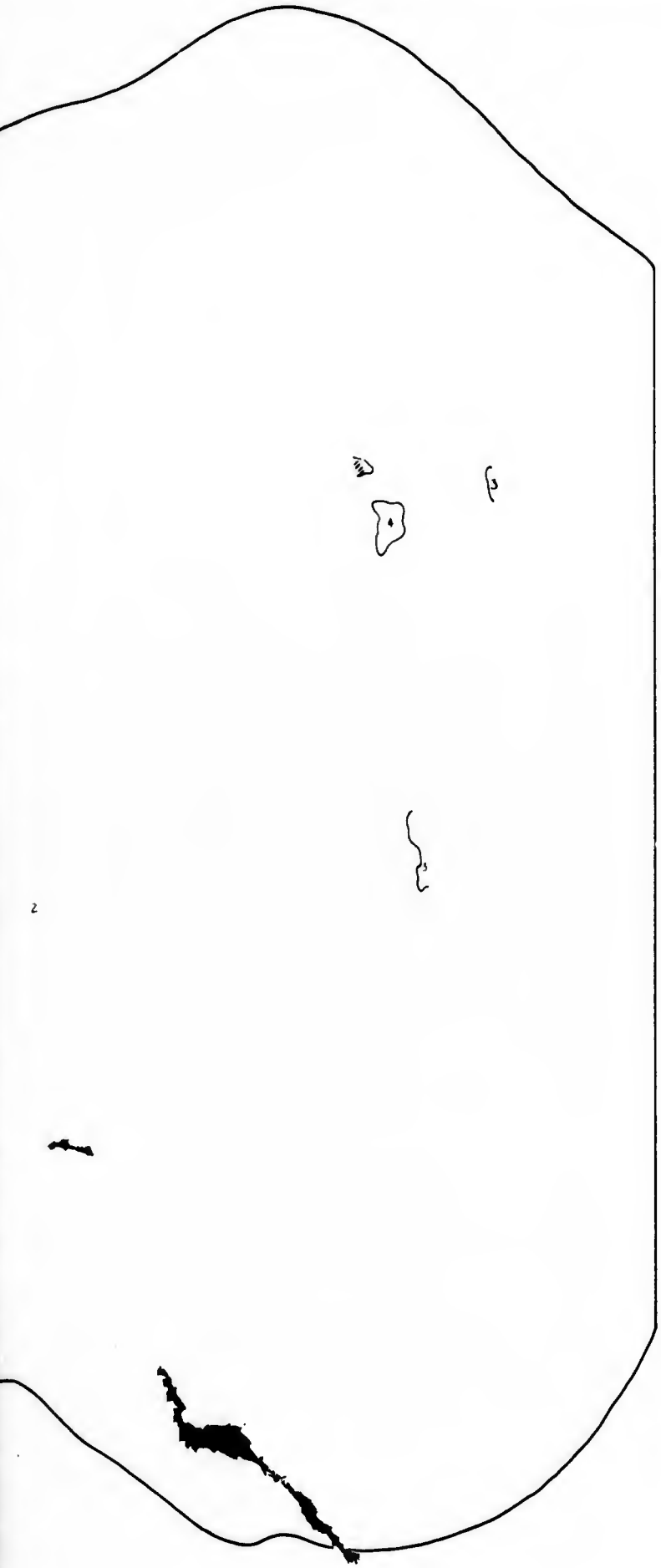
VEGETATION DENSITY
NO. STEMS 100 M²
1 ≤8
2 >8-32
3 >32-128
4 >128
5 NOT IDENTIFIED

REVISED
FACTOR MAP, FORT BELVOIR 1972
VEGETATION DENSITY

25<

PLATE B1 c





LEGEND

REMOVE LINE

2 REMOVE NUMBER

ADD LINE

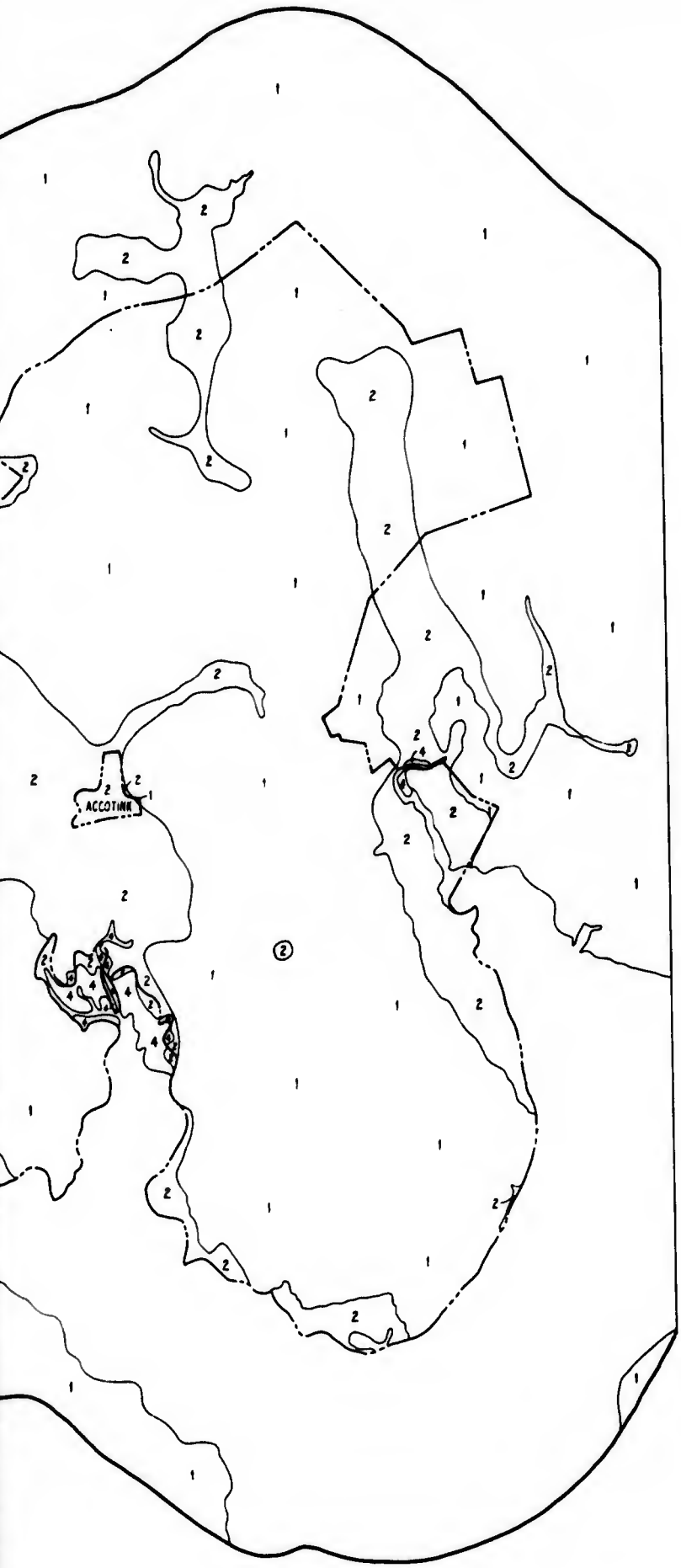
3 ADD NUMBER

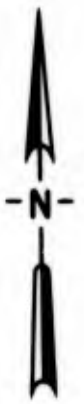
REVISIONS TO FACTOR MAP, FORT BELVOIR 1972 VEGETATION DENSITY

26<

PLATE B1 cr


ACCOTINK





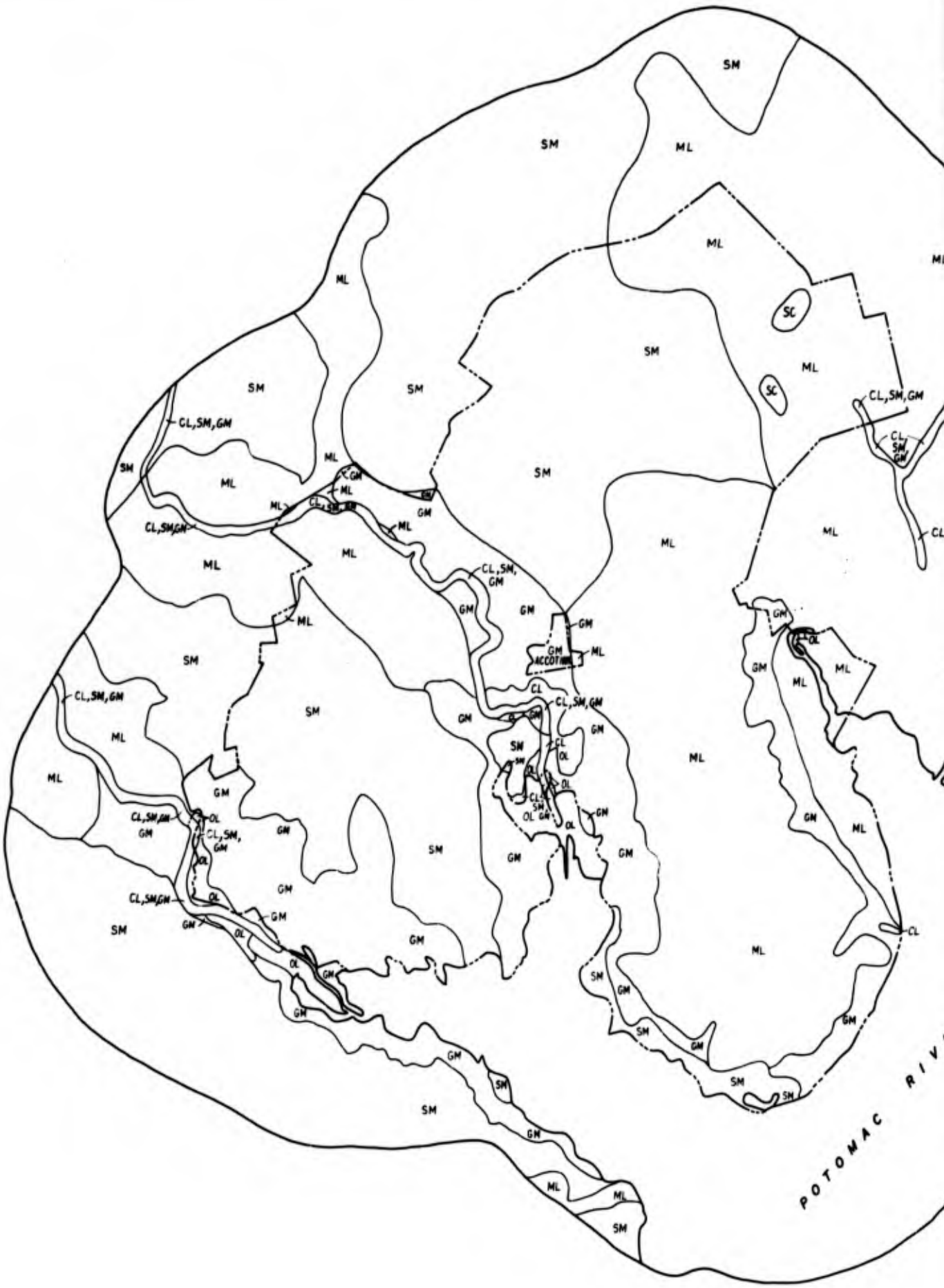
WILDLIFE HABITAT

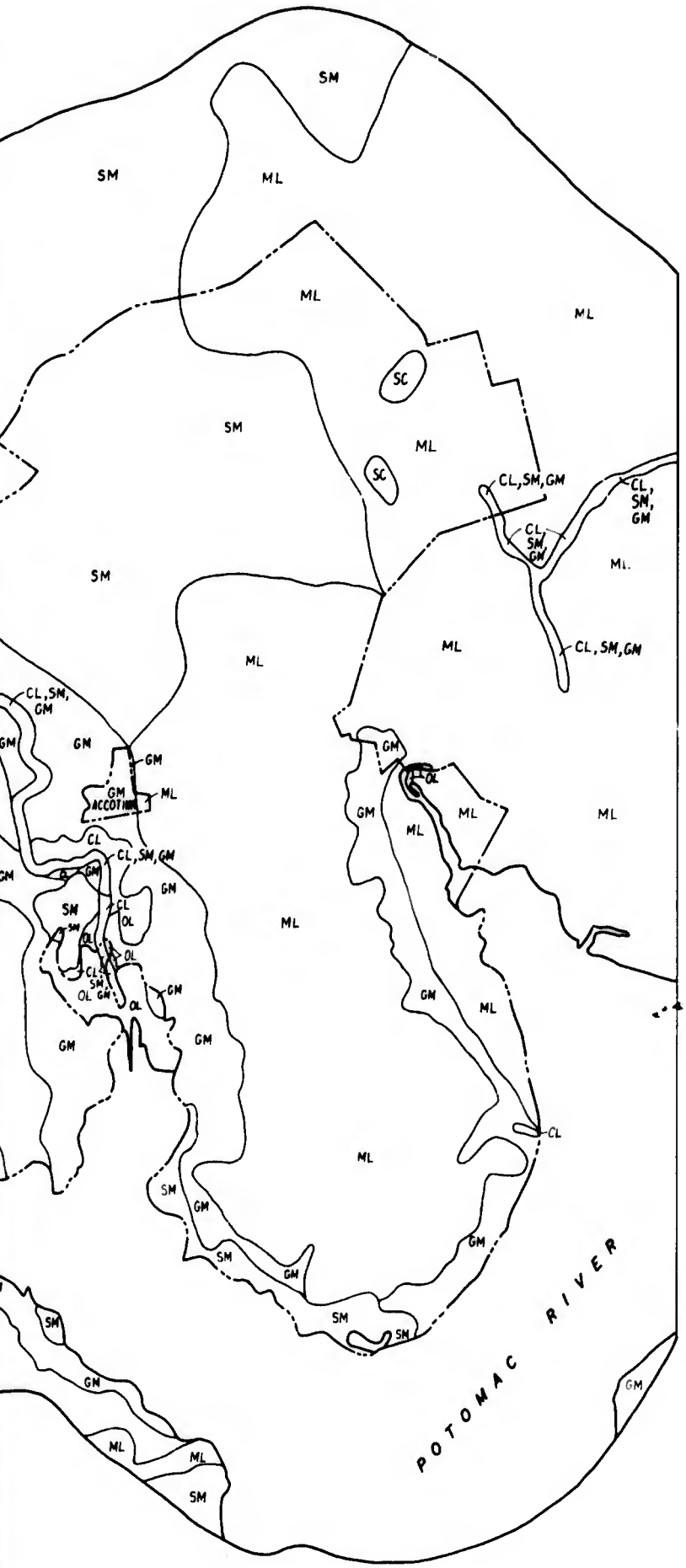
1 UPLAND
2 BOTTOMLAND
3 FRESHWATER MARSH
4 BRACKISH MARSH
5 SALT MARSH

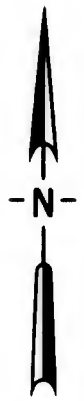
FACTOR MAP, FORT BELVOIR 1972
WILDLIFE HABITAT

27<

PLATE B1 d


SM
ML
SC
GM
OL
CL
CL,SM,GM
ACCOTINK
POTOMAC RIV





SOIL TYPE

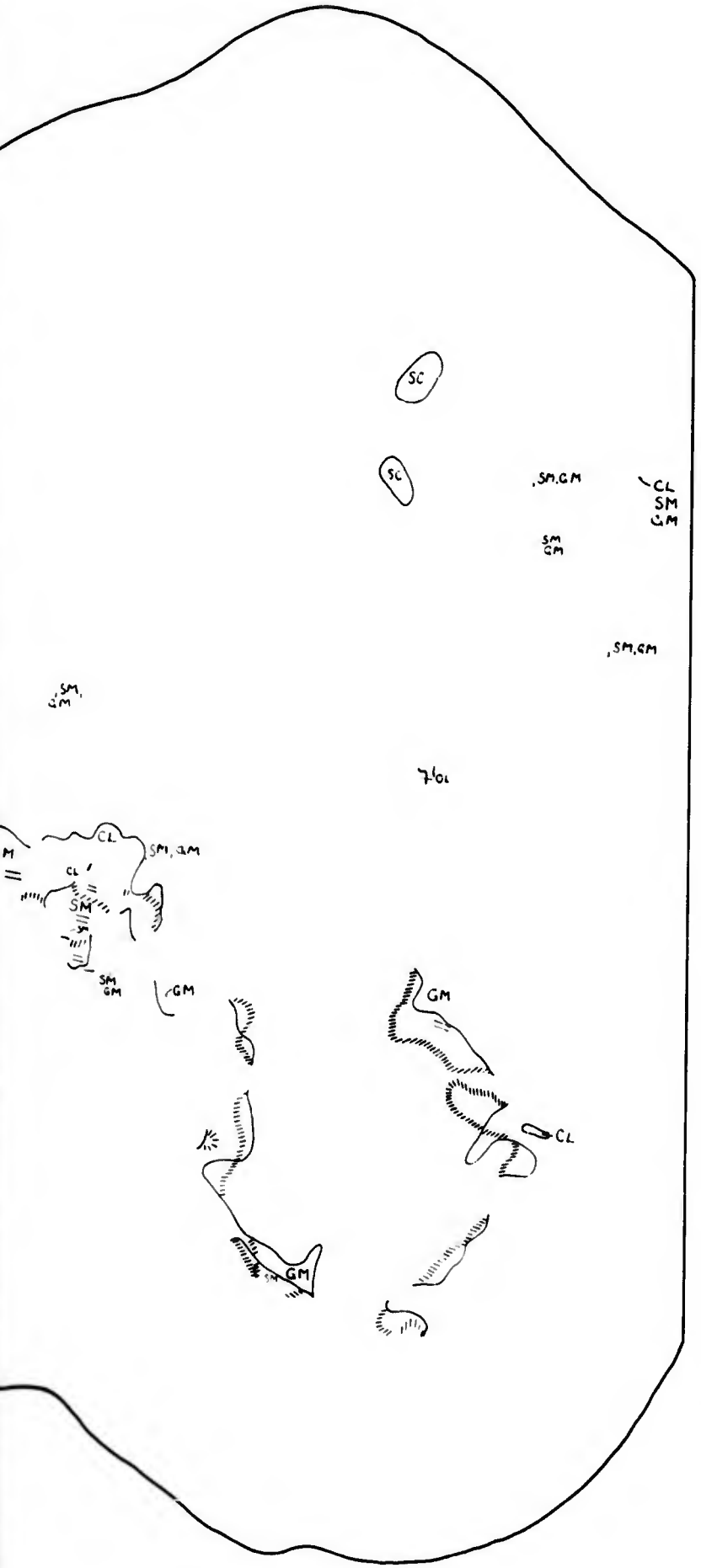
MAP CLASS	USCS SYMBOL	DESCRIPTION
1	GW	GRAVEL, WELL GRADED
2	GP	GRAVEL, POORLY GRADED
3	GM	SILTY GRAVEL
4	GC	CLAYEY GRAVEL
5	SW	SAND, WELL GRADED
6	SP	SAND, POORLY GRADED
7	SM	SILTY SAND
8	SC	CLAYEY SAND
9	ML	INORGANIC SILTS, CLAYEY SILTS
10	MH	ELASTIC SILTS
11	CL	LOW-TO-MEDIUM PLASTIC CLAYS, SANDY OR GRAVELLY CLAYS
12	CH	HIGHLY PLASTIC CLAYS
13	OL	ORGANIC CLAYS OR SILTS, LOW PLASTICITY
14	OH	ORGANIC CLAY, MEDIUM-TO-HIGH PLASTICITY
15	PT	PEAT AND OTHER HIGHLY ORGANIC SOILS

REVISED
FACTOR MAP, FORT BELVOIR 1972
SOIL TYPE

28<

PLATE B1 e

SC
SC
SM,GM
SM GM
SM,GM
SM,GM
SM,GM
SM, GM
7/0L
SM,GM
GM
CL
SM,GM
CL
SM
SM GM
GM
SM GM
SM
CL
CL
SM
GM
GM
CL
GM



LEGEND

- REMOVE LINE
- REMOVE NUMBER
- ADD LINE
- 3 ADD NUMBER

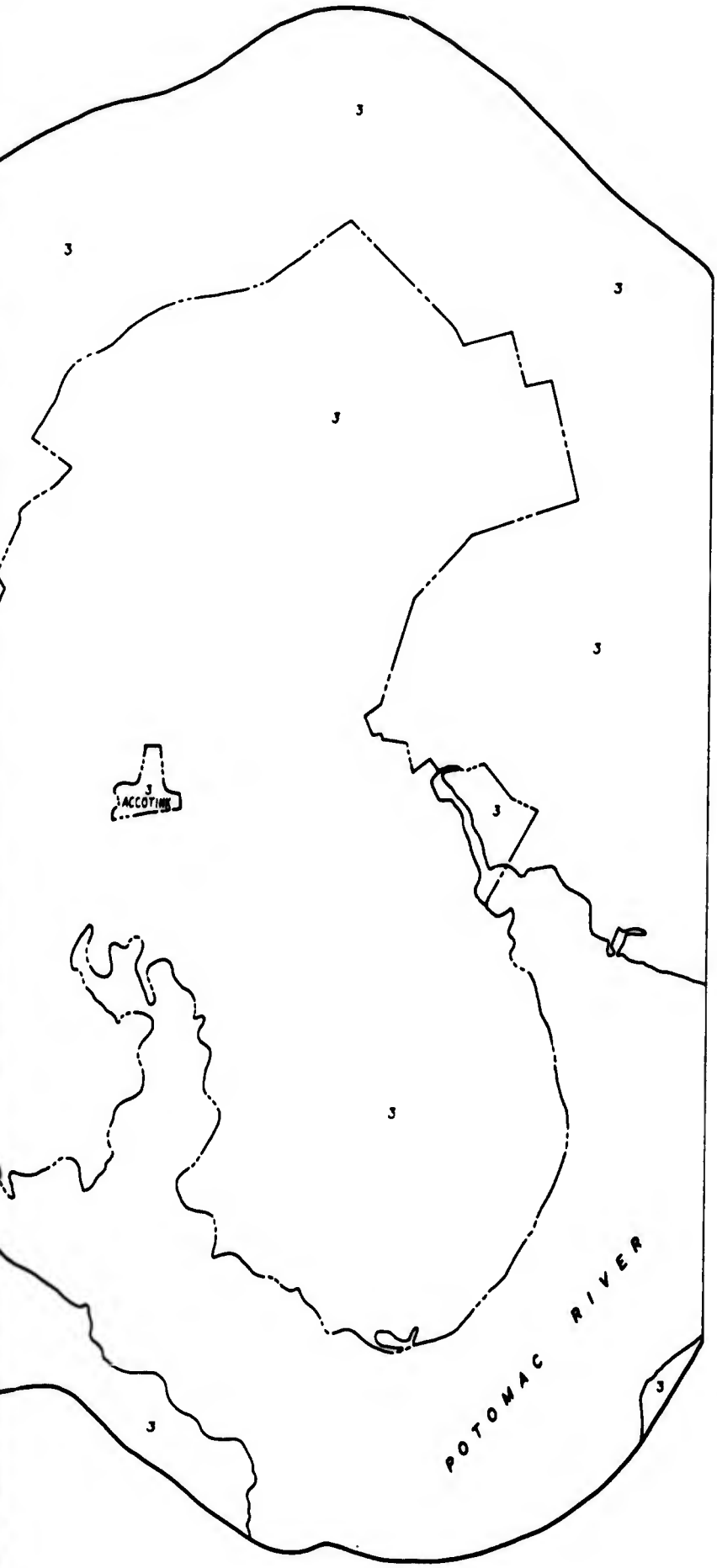
REVISIONS TO FACTOR MAP, FORT BELVOIR 1972

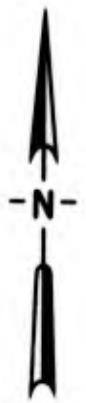
SOIL TYPE

29<

PLATE B1 er


ACCOTINK
POTOMAC RIVER



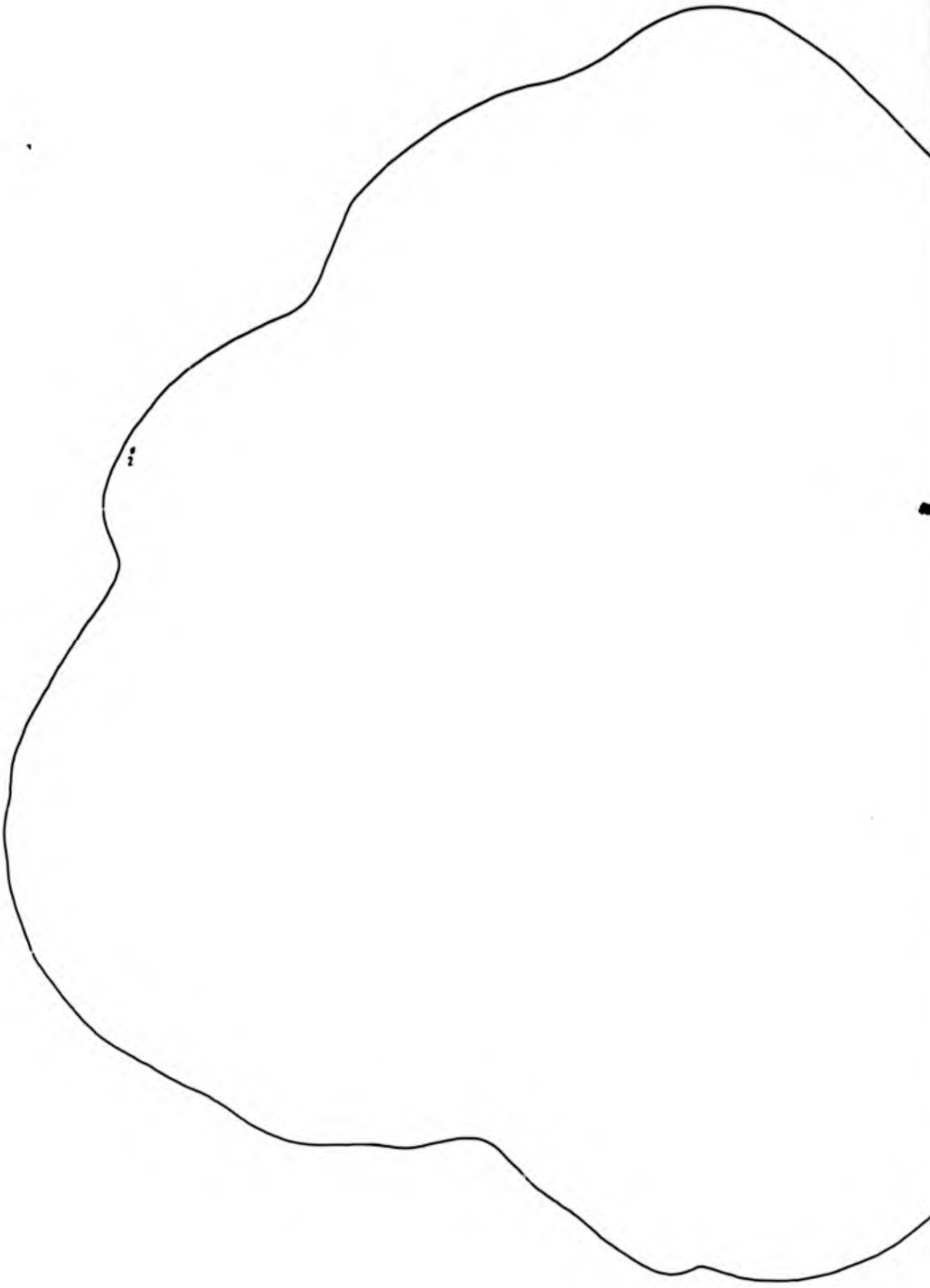


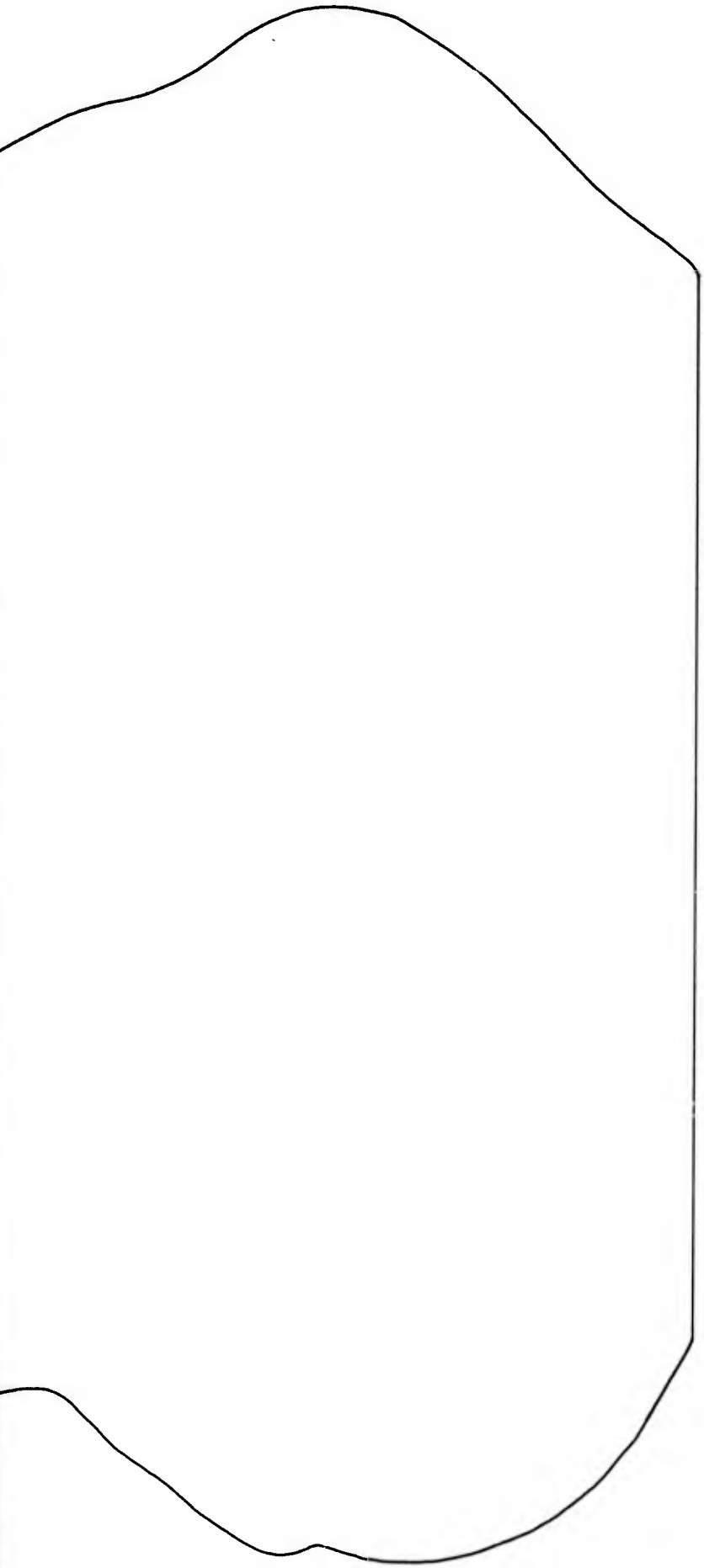
DEPTH TO BEDROCK, M
1. ≤1
2. >1-3
3. >3

REVISED
FACTOR MAP, FORT BELVOIR 1972
DEPTH TO BEDROCK

30<

PLATE B1 f





LEGEND

REMOVE LINE

2 REMOVE NUMBER

10 ADD LINE

3 ADD NUMBER

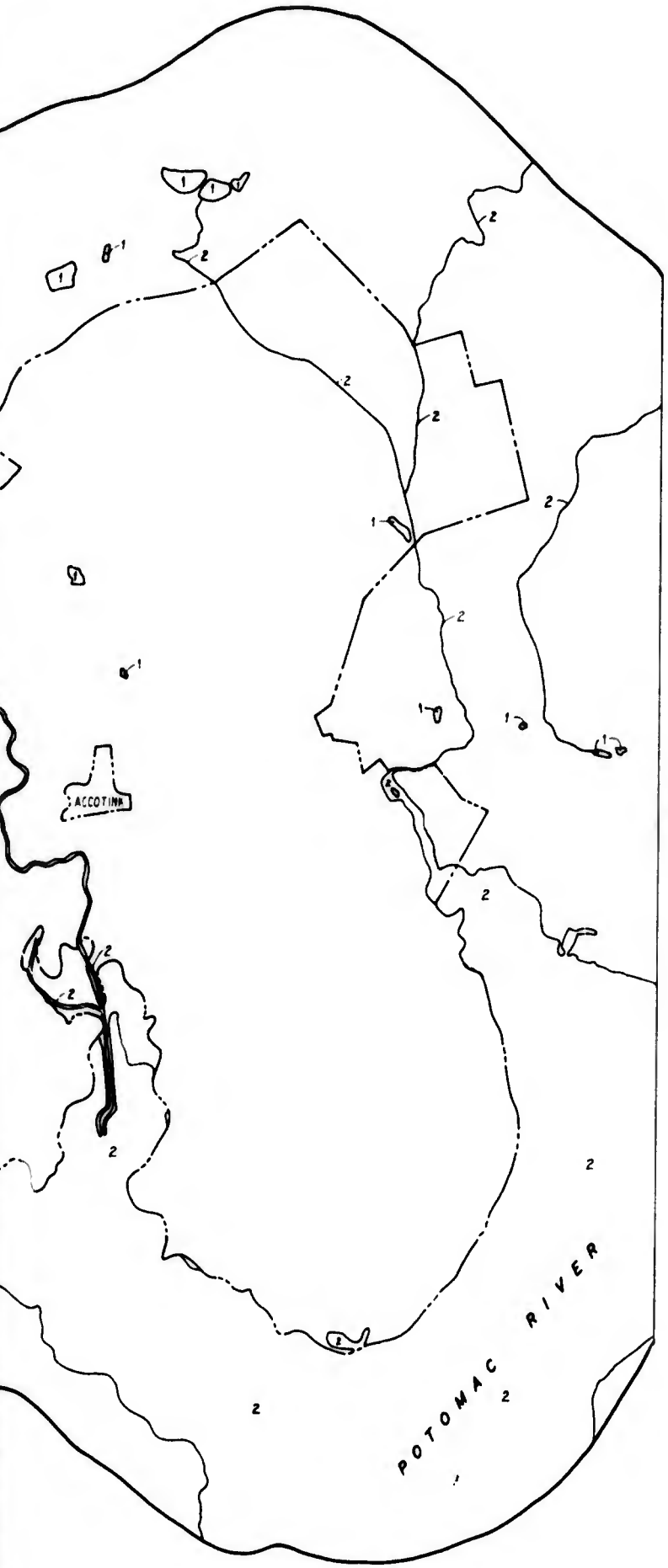
REVISIONS TO FACTOR MAP, FORT BELVOIR 1972

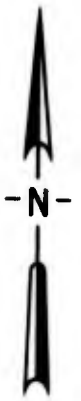
DEPTH TO BEDROCK

31<

PLATE B1 fr


ACCOTINK
POTOMAC





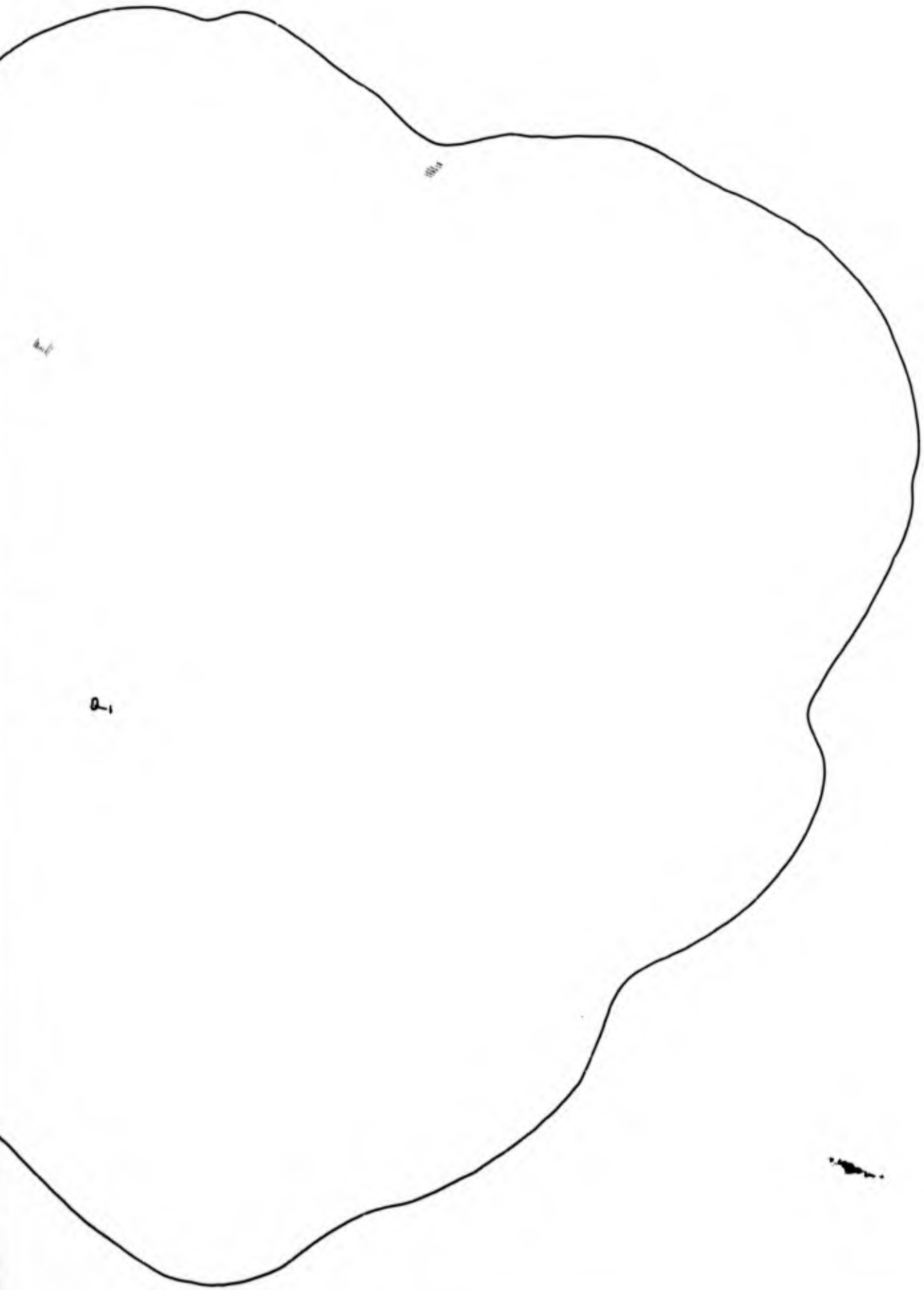
SURFACE WATER

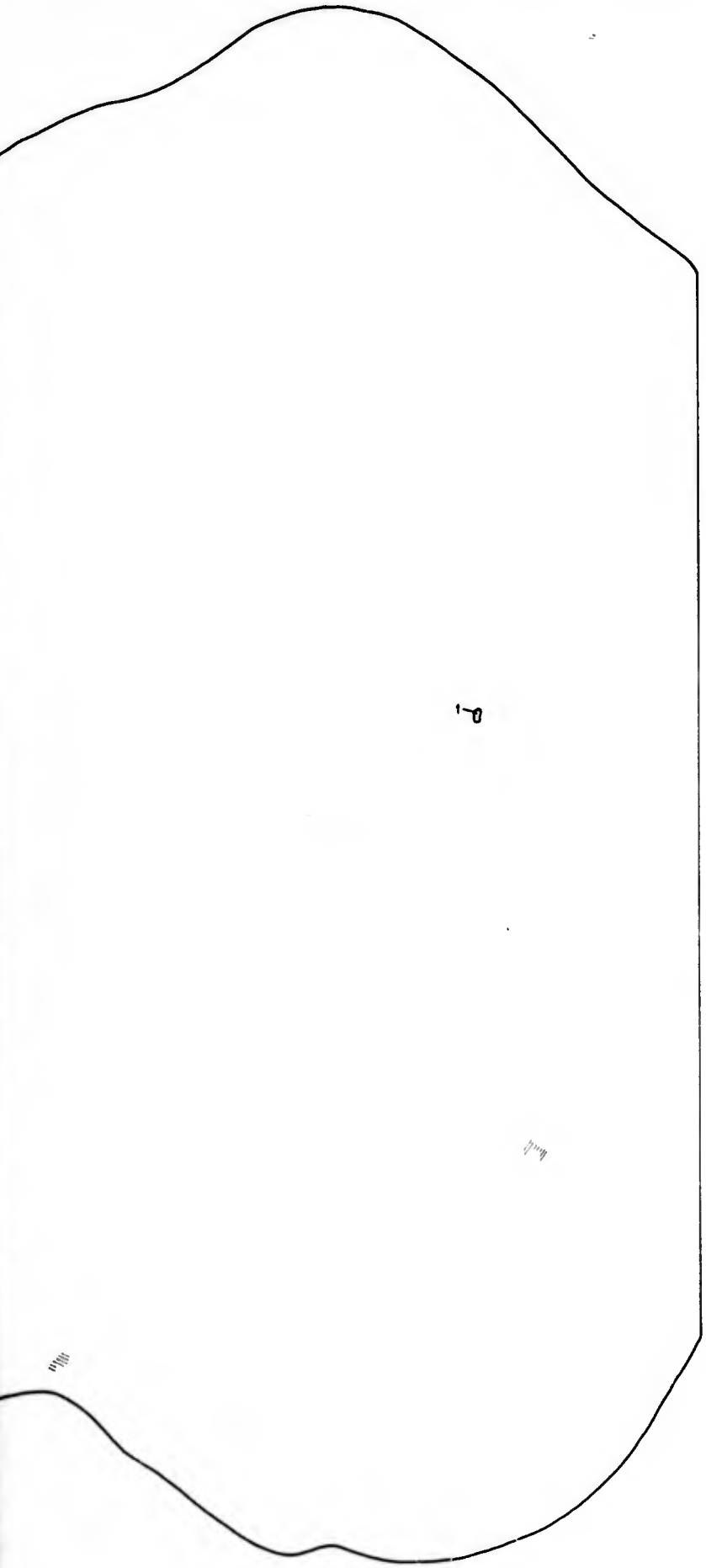
1 LAKES AND PONDS
2 RIVERS AND STREAMS
3 SPRINGS AND GEYSERS

REVISED
FACTOR MAP, FORT BELVOIR 1972
SURFACE WATER

32<

PLATE B1 g





LEGEND

REMOVE LINE

2 REMOVE NUMBER

ADD LINE

3 ADD NUMBER

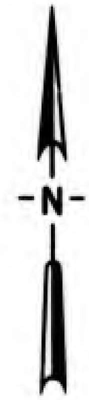
REVISIONS TO FACTOR MAP, FORT BELVOIR 1972

SURFACE WATER

33<

PLATE B1 gr


ACCOTINK



DEPTH TO GROUNDWATER, M

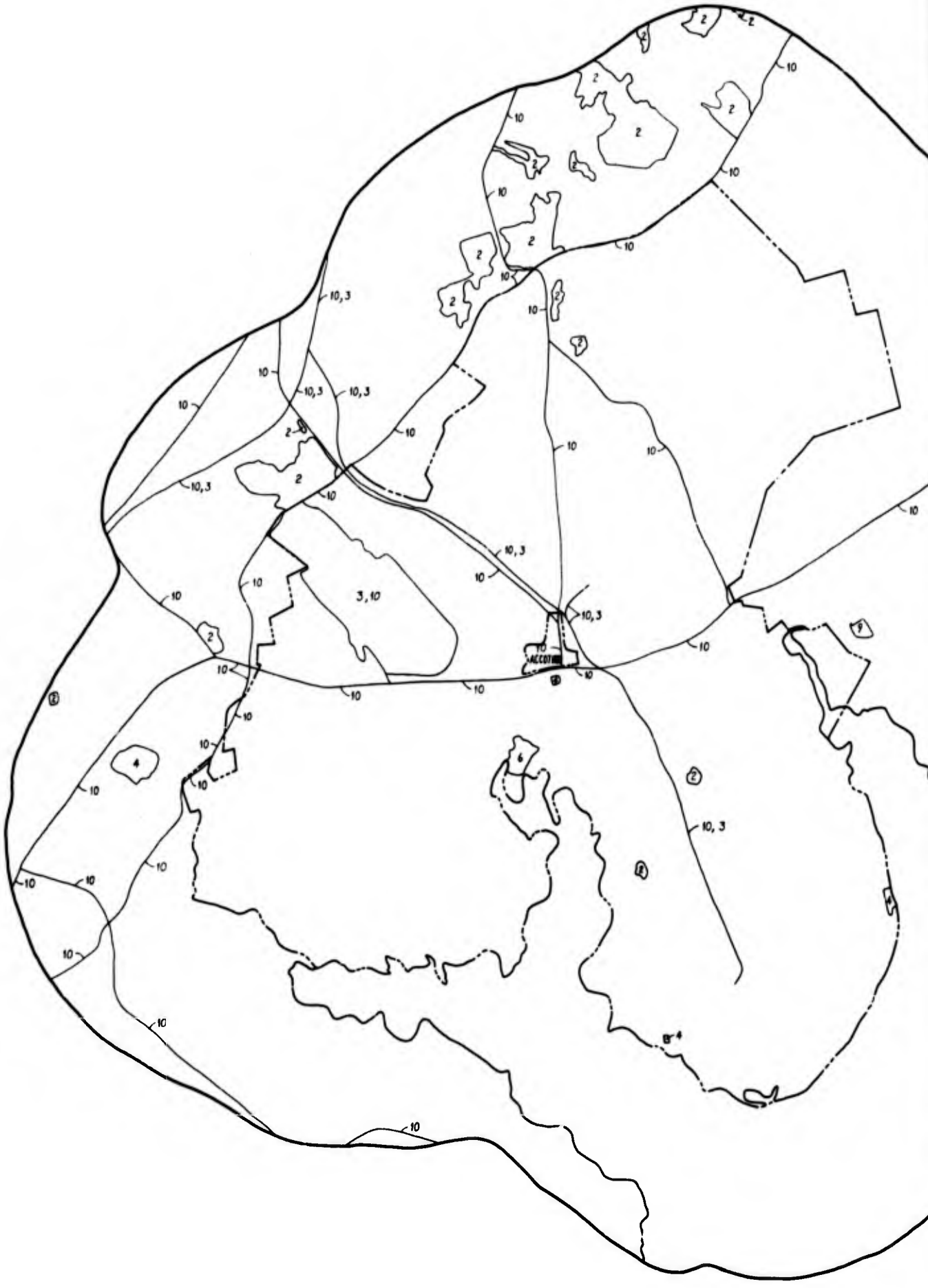
1. $\pm$2 RANGE (METERS)
2. >2

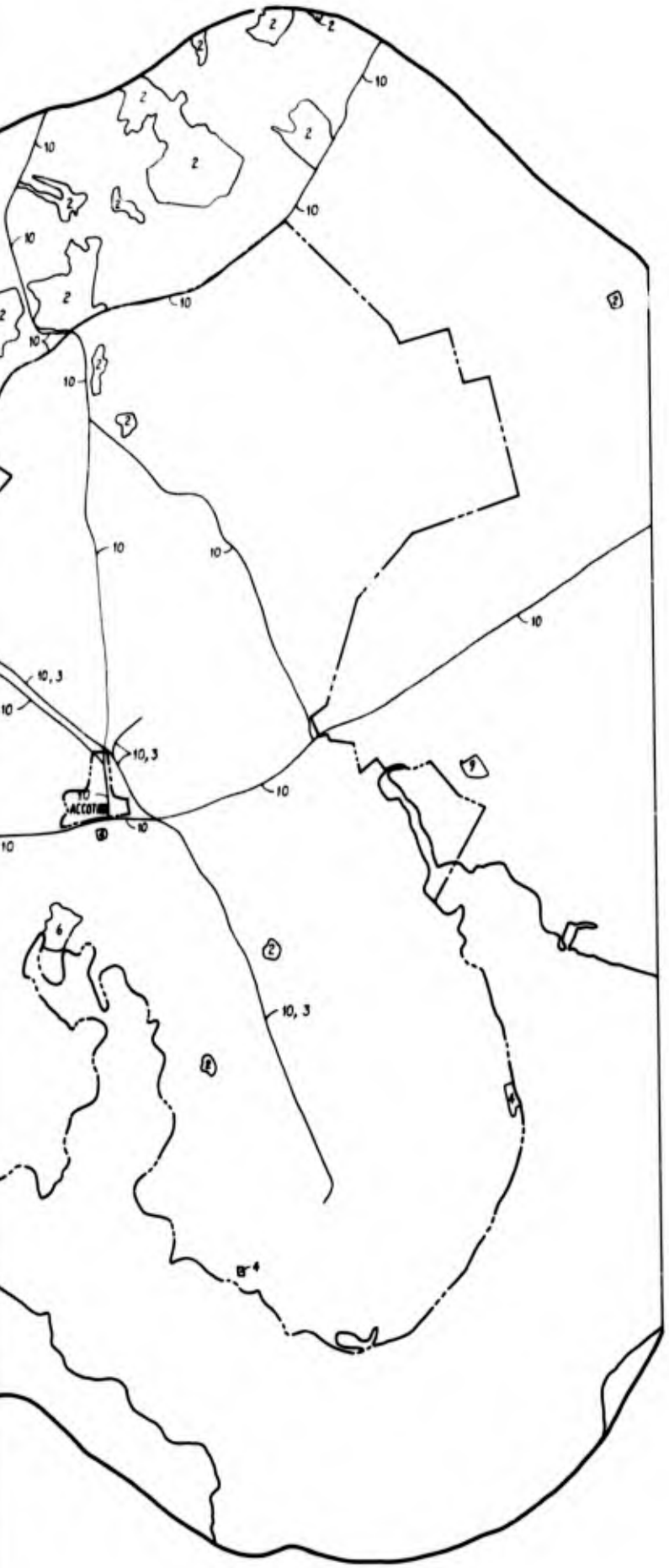
FACTOR MAP, FORT BELVOIR 1972

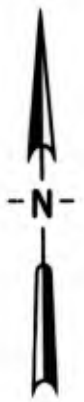
DEPTH TO GROUNDWATER

34<

PLATE B1 h


2
10
10, 3
3, 10
4
6
ACCOTINK





POLLUTION SOURCES

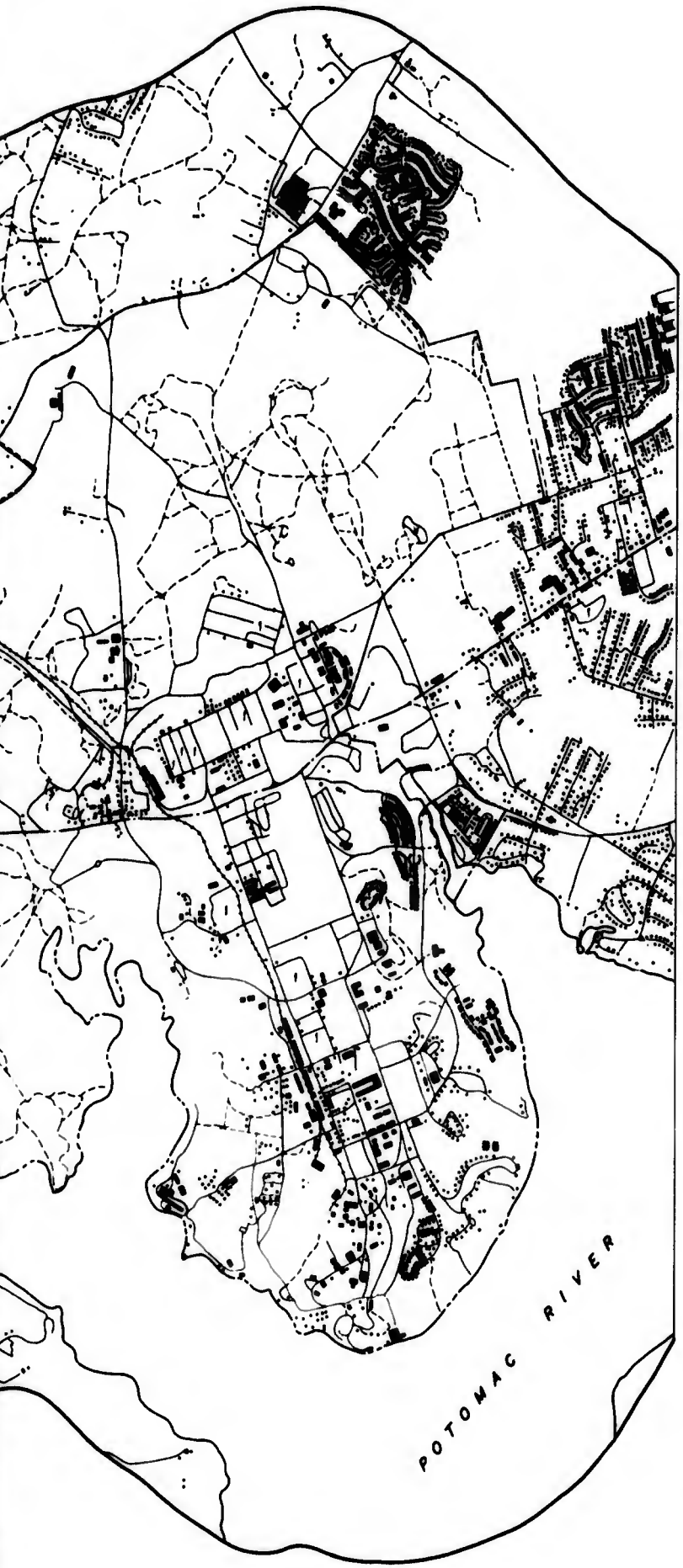
1 GAS DISPERSED IN AIR
2 SOLIDS DISPERSED IN AIR
3 GAS AND SOLIDS DISPERSED IN AIR
4 CHEMICALS DISPERSED IN WATER
5 ORGANICS DISPERSED IN WATER
6 CHEMICALS AND ORGANICS DISPERSED IN WATER
7 CHEMICALS DISPERSED ON LAND
8 ORGANICS DISPERSED ON LAND
9 CHEMICALS AND ORGANICS DISPERSED ON LAND
10 NOISE

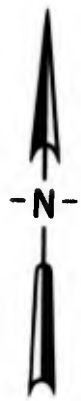
FACTOR MAP, FORT BELVOIR 1972
POLLUTION

35<

PLATE B1 i

POTOMAC RIVER





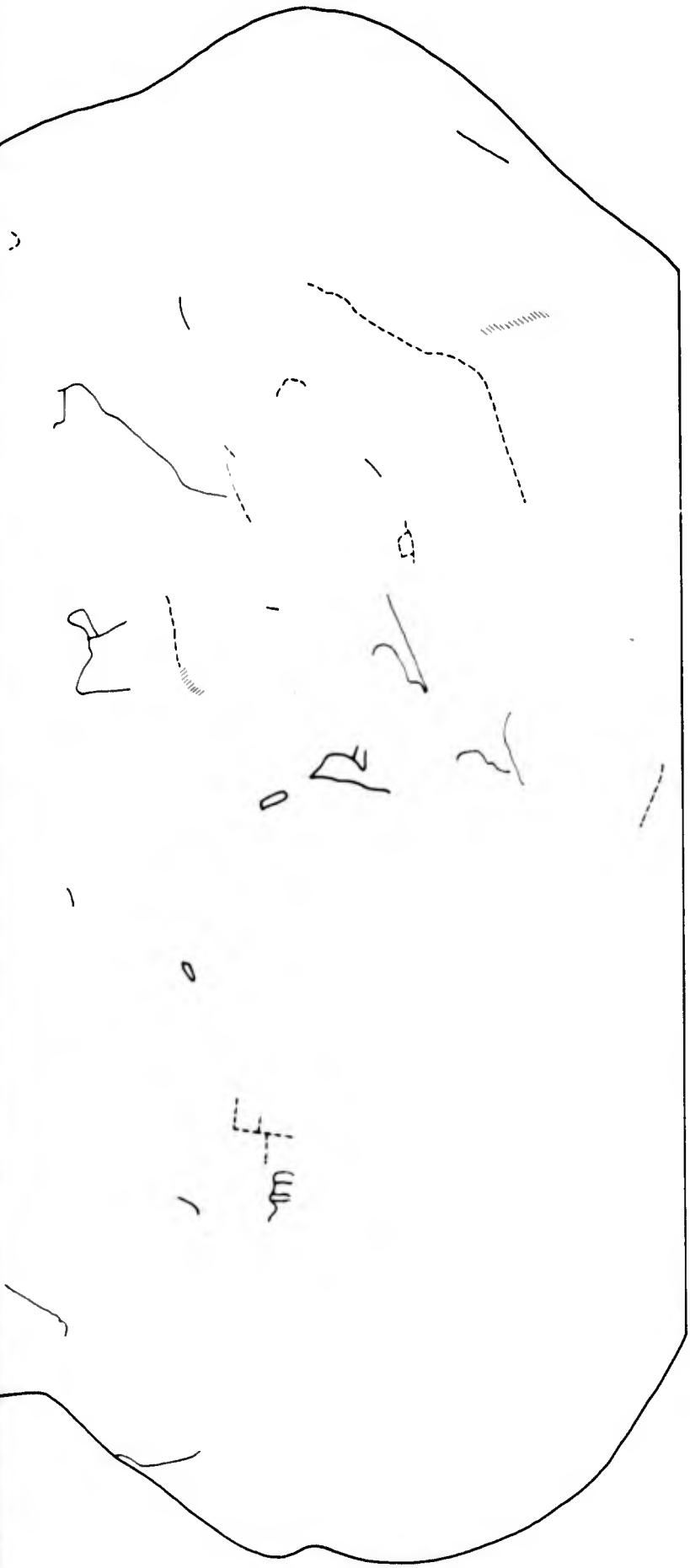
CULTURAL FEATURES

1 BUILDINGS
2 AIRPORTS
3 ROAD, 4-LANE, HARD-SURFACED
4 ROAD, 2-LANE, HARD-SURFACED
5 ROAD, UNSURFACED
6 RAILROAD, SINGLE-TRACK
7 RAILROAD, MULTIPLE-TRACK

REVISED
FACTOR MAP, FORT BELVOIR 1972
CULTURAL FEATURES

36<

PLATE B1 j



LEGEND

REMOVE LINE

ADD LINE

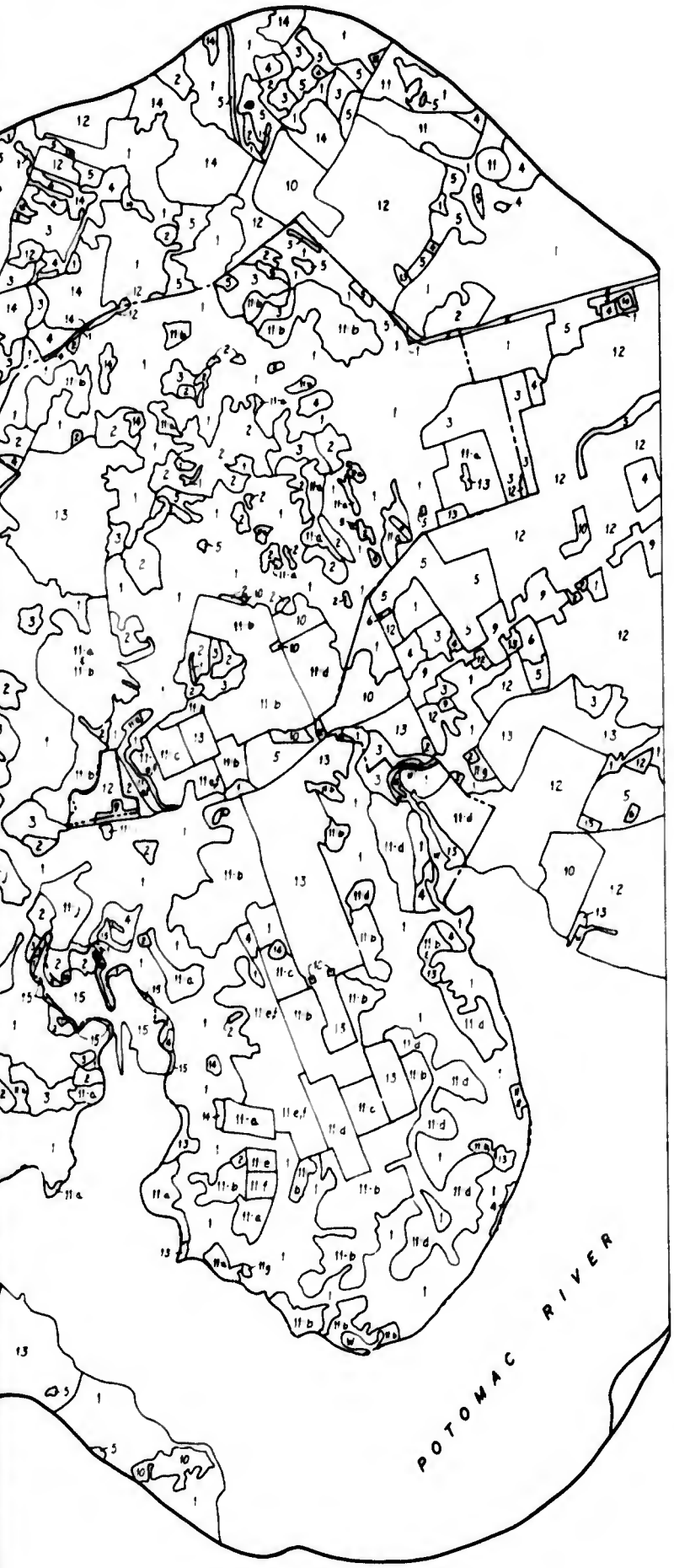
REVISIONS TO FACTOR MAP, FORT BELVOIR 1972

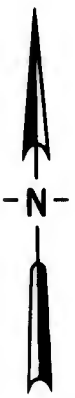
CULTURAL FEATURES

37<

PLATE B1 jr


POTOMAC





LAND-USE FACTORS

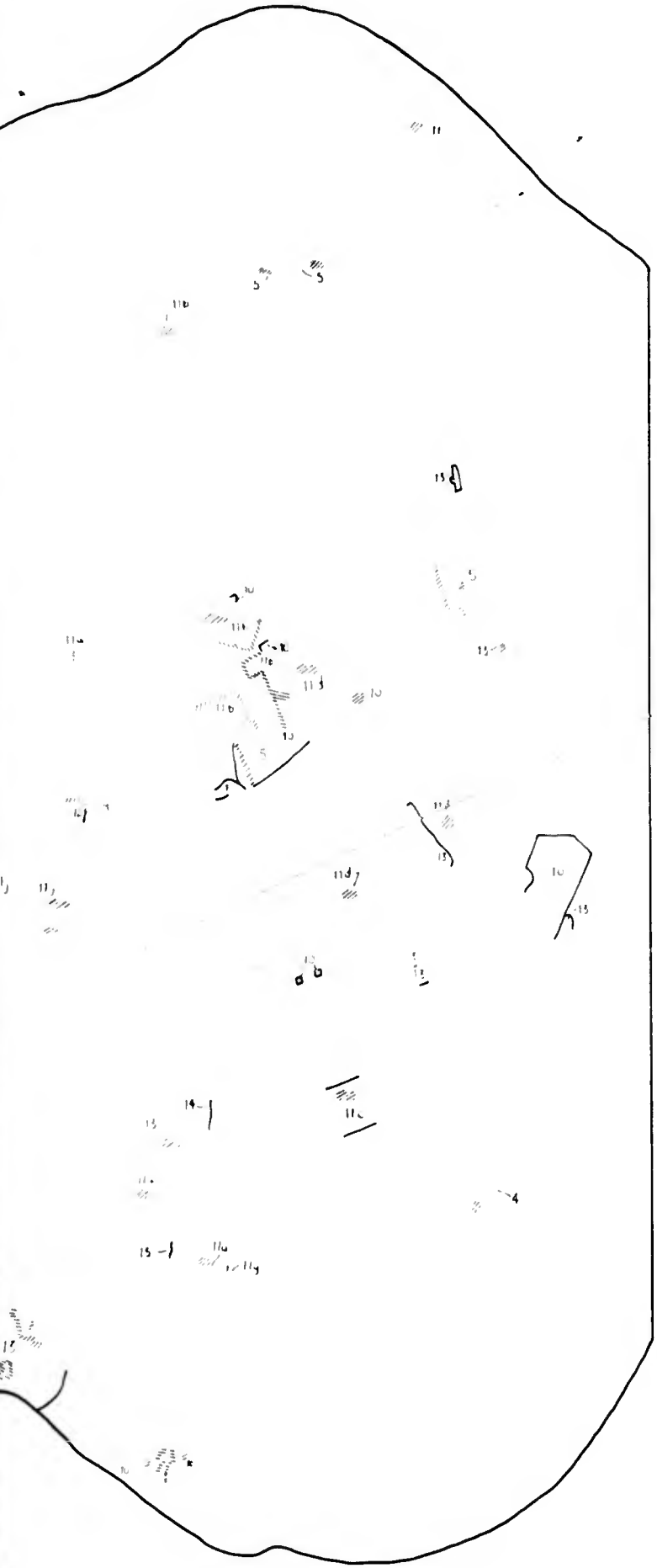
1 DECIDUOUS WOODLAND
2 CONIFEROUS WOODLAND
3 MIXED WOODLAND
4 SCRUB
5 GRASSLAND
6 CROPS
7 ORCHARDS AND VINEYARDS
8 INDUSTRIAL
9 COMMERCIAL
10 INSTITUTIONAL AND RELIGIOUS
11 GOVERNMENTAL COMPLEX (UNDIFFERENTIATED)
- a TRAINING AREAS
- b ADMINISTRATIVE BUILDINGS AND AREAS
- c TROOP HOUSING
- d FAMILY HOUSING
- e OPEN STORAGE
- f COVERED STORAGE
- g POLLUTION CONTROL
- h AIRFIELD
- i UTILITIES
- j SANITARY FILL

12 RESIDENTIAL
13 RECREATIONAL
14 MINING AND QUARRYING
15 MARSHLAND

REVISED
FACTOR MAP, FORT BELVOIR 1972
LAND USE

38<

PLATE B1 k



LEGEND

REMOVE LINE

2 REMOVE NUMBER

ADD LINE

3 ADD NUMBER

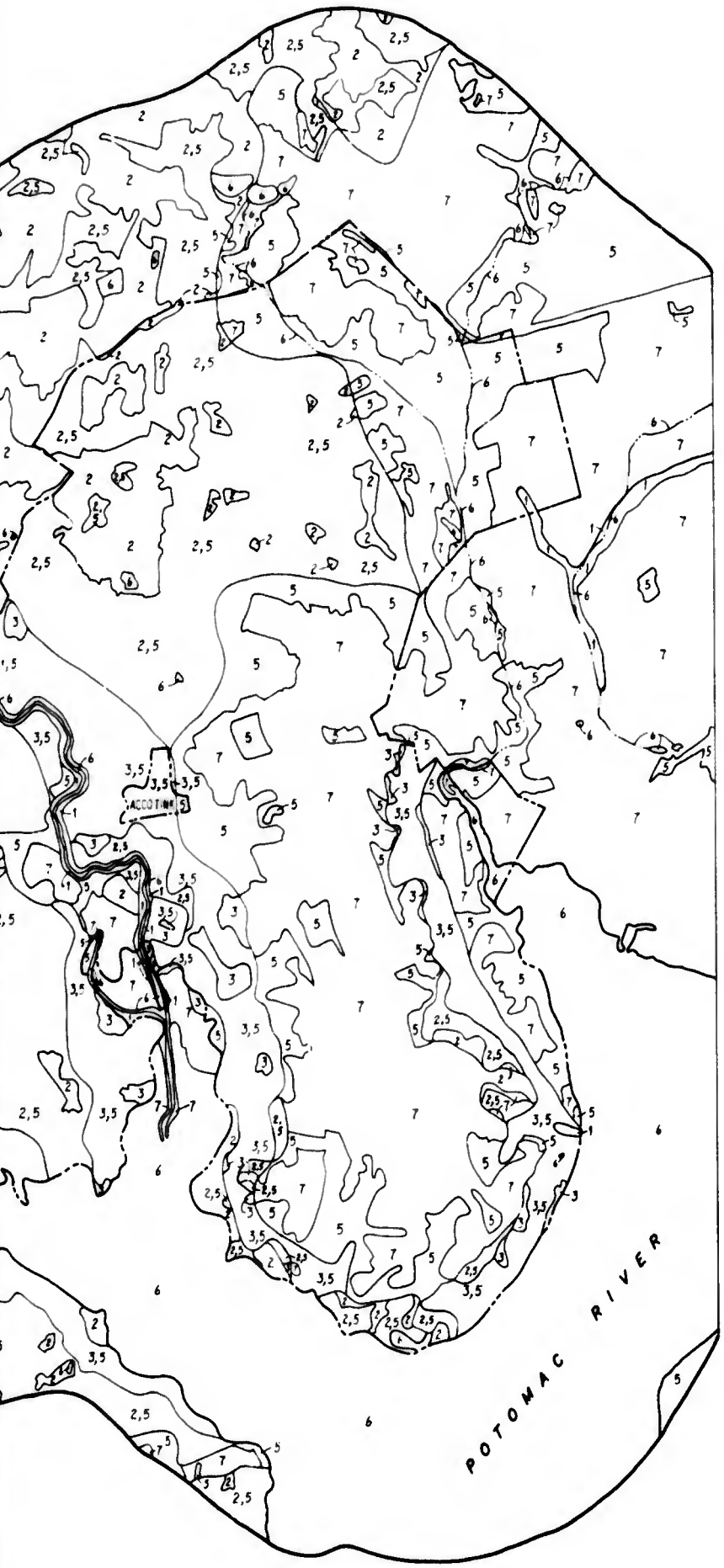
REVISIONS TO FACTOR MAP, FORT BELVOIR 1972

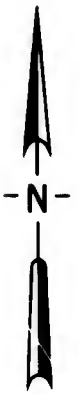
LAND USE

39<

PLATE B1 kr


ACCOTINK
POTOMAC RIVER





NATURAL RESOURCES

1 CLAY, <2m OVERBURDEN
2 SAND, <2m OVERBURDEN
3 GRAVEL, <2m OVERBURDEN
4 BEDROCK, <2m OVERBURDEN
5 TIMBER, ≥8m IN HEIGHT
6 SURFACE WATER
7 ABSENT

REVISED
FACTOR MAP, FORT BELVOIR 1972
NATURAL RESOURCES

40<

PLATE B1 1

LEGEND

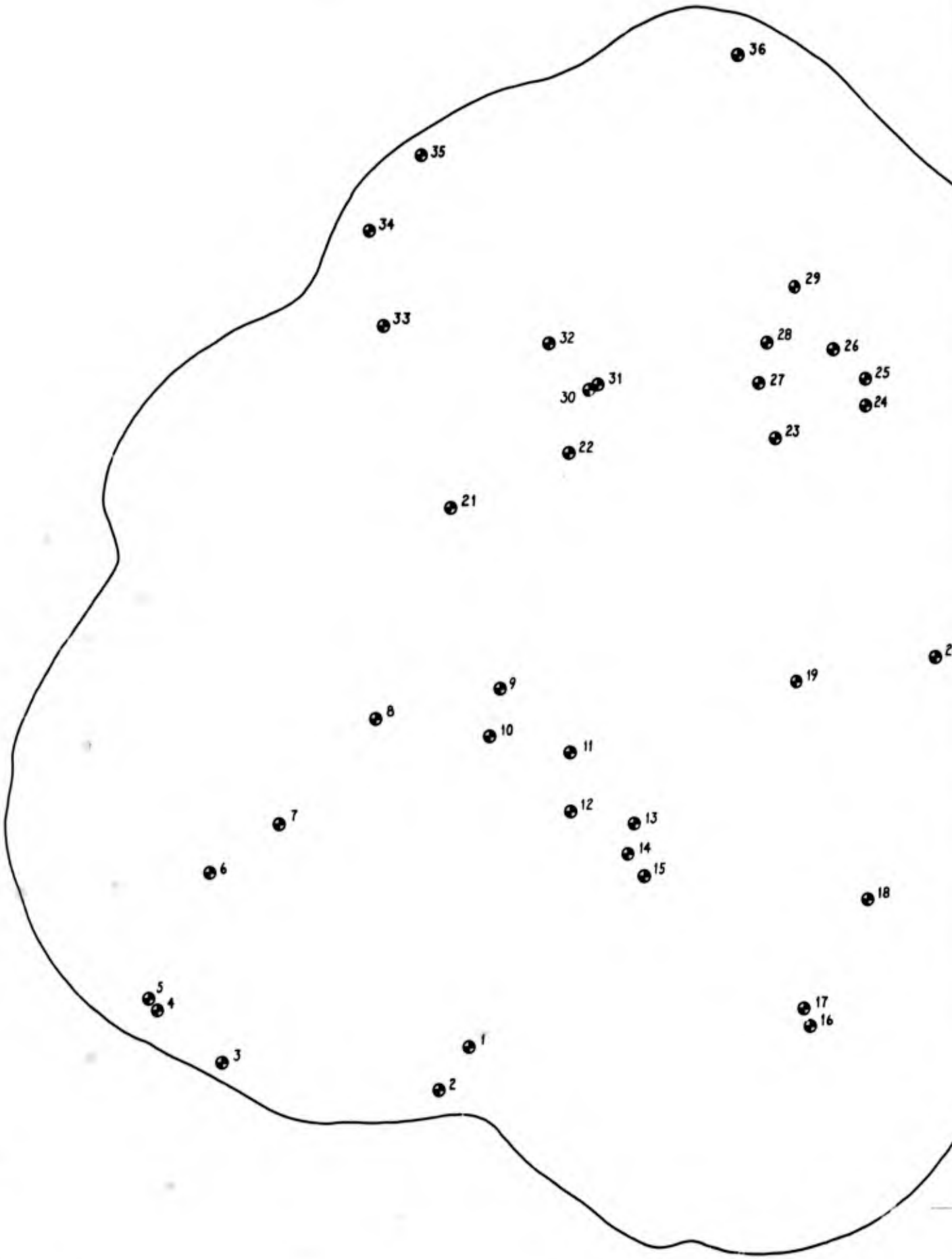
- REMOVE LINE
- 2 REMOVE NUMBER
- ADD LINE
- 3 ADD NUMBER

REVISIONS TO FACTOR MAP, FORT BELVOIR 1972

NATURAL RESOURCES

41<

PLATE B1 Ir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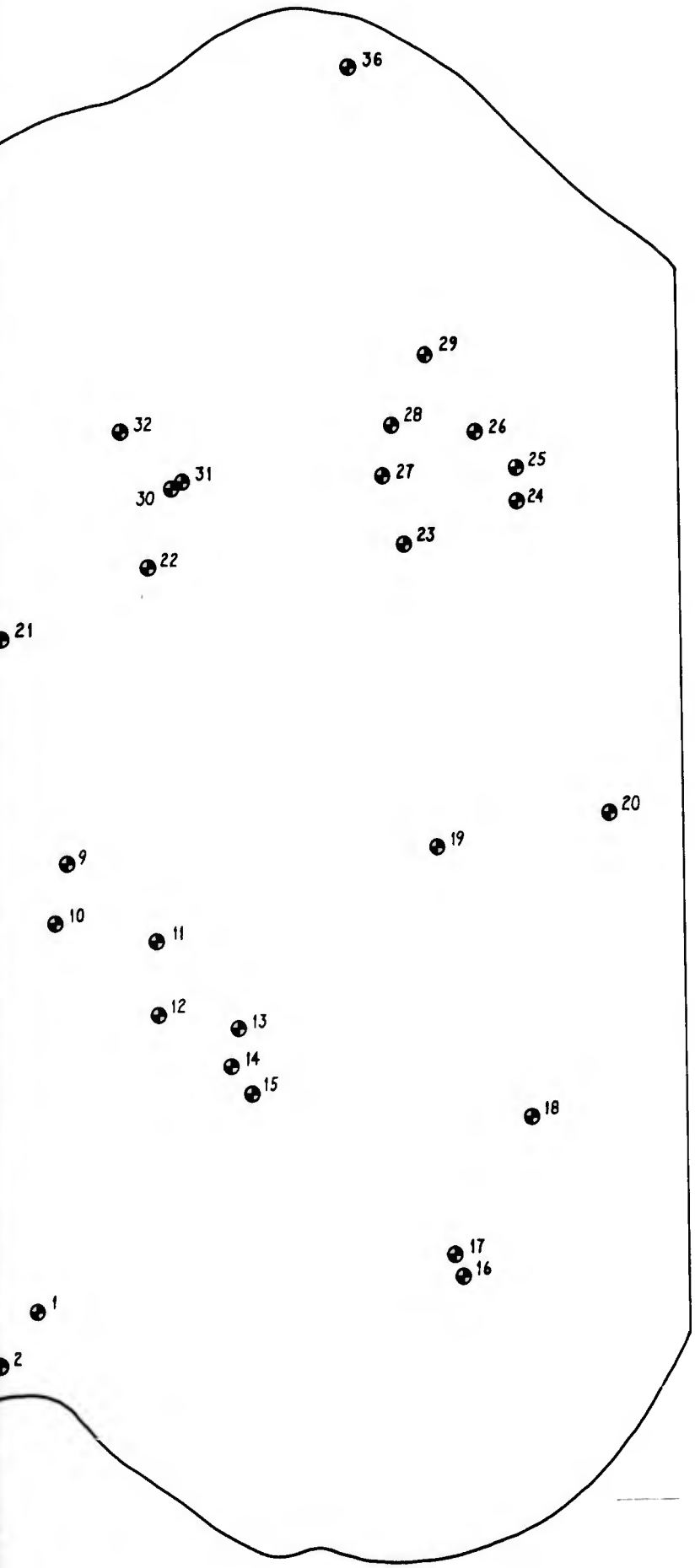

LEGEND

1 SAMPLE SITE

FT BELVOIR, VA.

ENVIRONMENTAL DATA COLLECTION SITES

42<

PLATE B2

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Shamburger, John H
Application of remote sensors to Army facility management; Appendix B: Validation of environmental maps produced through air-photo interpretation, by John H. Shamburger [and] Harry K. Woods. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1975.
1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Technical report M-74-2, Appendix B)
Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C.

1. Air-photo interpretation. 2. Environmental factors. 3. Environmental maps. 4. Fort Belvoir, Va. 5. Military facilities. 6. Remote sensors. I. Woods, Harry K., joint author. II. U. S. Army. Corps of Engineers. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Technical report M-74-2, Appendix B)
TA7.W34 no.M-74-2 App.B