SOME COMMENTS ON CERTAIN TECHNICAL ASPECTS OF GEOGRAPHIC INFORMATION SYSTEMS

by

Michael F. Dacey and Duane F. Marble

TECHNICAL REPORT NO. 2

of

ONR Task No. 389-142
Contract Nonr 1228(35)

OFFICE OF NAVAL RESEARCH

GEOGRAPHY BRANCH

Department of Geography
Northwestern University
Evanston, Illinois

December 1965

Funding Provided by
Remote Sensing Program
Office of Space Sciences and Applications
National Aeronautics and Space Administration

SOME COMMENTS ON CERTAIN TECHNICAL ASPECTS OF GEOGRAPHIC INFORMATION SYSTEMS

by

Michael F. Dacey

and

Duane F. Marble

Department of Geography
Northwestern University

ABSTRACT

This document is intended to serve as a general preface to subsequent project reports of a more technical and specialized nature. Special attention is directed toward the work being carried on in the areas of spatial statistics and two-dimensional languages, and the relevance of this work to the development of generalized geographic information systems.

SOME COMMENTS ON CERTAIN TECHNICAL ASPECTS OF GEOGRAPHIC INFORMATION SYSTEMS

Michael F. Dacey and Duane F. Marble
Department of Geography
Northwestern University
Evanston, Illinois

Ordinary maps, photographs, images and similar cartographic devices are basic geographic research tools. The advantages and efficiencies of the map* for representing the distribution and arrangement of spatially located data are well known and generally appreciated. The detailed textual discussions that frequently accompany relatively simple maps suggest that he who first stated "a picture is worth a thousand words" was off by several factors of ten. The primary function of a geographic information system is to make spatially oriented information available in a usable form. The succinct handling of data by the map is evidently a basic source of many problems confronting the design and subsequent operation of any such system. While for some needs it may be adequate simply to display an appropriate map, for many other purposes it is required to summarize the map by reduction to a set of words and numbers. Where the map itself is an adequate representation, a geographic information system is required to produce maps from one or more other data sets contained within the system; the problems occurring at this level largely concern the manipulation of mapable information sets. In other and more common situations, the geographic information system is

*In this report, "map" is used as a generic term referring to any of the wide variety of methods for representing spatially located information.

required to reduce several or many map patterns and spatial data sets to words and numbers. The problems occurring at this level concern both the manipulation of mapped information and the expression of the resulting areal data in a common linguistic or mathematical format.

The design of a geographic information system that efficiently satisfies the data needs of a community of users must take into account the manifold aspects of collection, codification, storage, retrieval, and analysis of spatially located and other kinds of data. Two research areas examined as part of the present investigation, and believed to be of fundamental importance to the design and operation of a geographic information system, are discussed in this report. One class of problems concerns the formal structure of a system for the collection, storage, and retrieval of spatially located information. The second class of problems concerns the summary description and analysis of information having a spatial arrangement and distribution. The purpose of this note is, on one hand, to identify problems that have attracted our interests as particularly relevant to the geographic data system and, on the other hand, to describe in very general terms the strategies adopted for approaching the solutions. This general survey provides an orientation to the more specialized reports generated by this study.

Spatial Statistics

The description or analysis of spatially located information is, in many cases, largely a study of the geometric patterns formed by the arrangement and distribution of objects. The description of pattern frequently requires reduction of the subtleties of arrangement and distribution displayed by the map to a form susceptible to mathematical or statistical analysis. Statistical or probabilistic methods are generally employed because the patterns on maps seldom have the high degree of regularity required for algebraic description, such as the space groups used with considerable success in crystallography.[1] This concentration upon statistical and probabilistic approaches to pattern is consistent with the recent orientation of geographic and other social science research.

There exists a rather extensive literature on the general topics of geometrical probabilities and stochastic processes in two or three-dimensional space. Though many of these results may be suitable for the description and analysis of spatial data, this literature has generally not been exploited by geographers, planners, economists, engineers and others who would be largely responsible for the analysis of the areal data sets produced by a geographic information system. Several reasons seemingly underlie the failure to utilize this knowledge. A major limitation is that much of the material pertinent to spatial analysis presumes considerable mathematical training and sophistication. Compounding this difficulty is that much of the literature has developed within an abstract context or in terms of applications generally unfamiliar to most users of geographic data. As examples we cite the Ising model of statistical physics which has direct applications to enumerative data on a county basis and the spectral analysis used, among other topics, for the study of wind waves.[2]

---

[1] Buerger, M. J. 1956. Elementary Crystallography, New York.

[2] Green, H. S, and Hurst, C. 1964. Order-Disorder Phenomena, New York.
Kinsman, B. 1965. Wind Waves, Princeton.

Still other methods have been developed in a context which loses the spatial pertinence to geographic research. For instance, the compound and generalized distributions developed for statistical ecology and actuary science lack the level of spatial articulation which is normally required in geographic research.[3]

This phase of the research may be viewed as a relatively extensive review of the statistical methods and probabilistic models which might be utilized by researchers, government officials, business people and other potential users of a geographic information system. This work is a review or summary statement in the sense it is largely restricted to known procedures and methods. It is not a review in the sense of being restricted to synthesis and codification of existing results. One important objective is to base the statistics and probabilistic methods upon a conceptual and theoretical basis which conforms to methodological tenets of cartographic analysis and map interpretation. Because of this orientation the derivation of known results frequently requires a basically different description of the underlying areal properties and processes.

One characteristic of reviews is the designation of areas and topics that have been neglected or not adequately developed. While the present effort has been no exception, there have also been developed a number of simple tools and properties that have not been readily available to the student of spatial relations and spatial processes. While the mathematican or mathematical statistician may consider a problem solved when he is able to give a generating or characteristic

---

[3]Kershaw, K. A. 1964. Quantitative and Dynamic Ecology, London.
Lundberg, O. 1965 - 2nd Ed. On Random Processes and Their Application to Sickness and Accident Statistics, Uppsala.

function, the user of these results often needs more detailed information and, possibly, even numbers. Accordingly, the preparation of the basic textual material has been accompanied by the tidying-up chore of obtaining specific equations from highly general results and the tabulation of moments, distribution functions and other basic properties of the more common statistical formulations applicable to spatial analysis.

By making basic information of this type accessible to potential users of a geographic information system it is anticipated that there will be a significant increase in the number of researchers who can significantly contribute to the spatial analysis of data resulting from geographic information system. Another justification for this material is the need to establish the available methods of description and analysis in order that the geographic information system may be structured to respond effectively to the demands of its users.

To reduce the task to manageable proportions, it has been necessary to establish priorities on the order in which the various types of statistical methods and probability models are examined. Initial emphasis has been placed on the following topics: the description of point patterns, the computation of measures of association or contiguity for a region partitioned into "counties" or "quadrats", and the spectral analysis of two-dimensional data. Further, where derivations are required for idealized or theoretical spatial processes the patterns are largely restricted to random and independent processes. These particular topics were selected on the grounds of relative simplicity, general applicability and relevance to geographic problems, as well as a somewhat representative sampling of the methods and models suitable for spatial description and analysis.

Spatial Languages

This part of the study was initiated in 1960, as unsupported research, and it reflects a continuing interest in the map as a medium of communication and as a research tool. This study was motivated by an observation (taken out of context) by Sir Arthur Eddington in introducing a mathematical construct to reduce the dimensionality of space to a reality investigation. He wrote:

> We have to express in mathematical symbolism what we are doing when we mention things; for if we have no conception of what we are doing, the result of our measurement would not persuade us to believe anything in particular. All our results are derived from the condition that the conceptual interpretation which we place upon result of measurement must be consistent with our conceptual interpretation of the process of measurement, we have to define symbols with properties that correspond precisely to the conceptions introduced.[1]

This remark generated the original investigation of the relation of symbols on maps and other cartographic devices to the things and concepts the symbols represent. On a continuing, but not intensive schedule, the structure and function of maps, map symbols and other spatial models have also been investigated. An important conclusion of these surveys was that maps, mathematical models, and other representations for spatial relations use a "language", but that this language differs in quite important respects from everyday language, programming languages or the formal languages commonly developed by logicians. The relation to language is stressed because basic linguistic concepts such as sign, sentence or proposition, syntax, and possibly, semantics, are recognizable features of cartographic models.

---

[1]Eddington, Sir Arthur. 1946. <u>Fundamental Theory</u>, Cambridge.

An important difference is that neighborhood and juxtaposition in two dimensions is not a simple generalization of the concatenation of language. The similarities suggest that cartographic models utilize a language that may be studied in the context of conventional linguistic concepts, but the differences suggest that cartographic models require concepts involving higher dimensionality. It appears that the language of maps is a two-dimensional language and that the study of this language must take into account its two-dimensional structure.

The present study on geographic information systems revived the interest in linguistic structure. Many of the results obtained from the study of cartographic models are considered relevant to more general systems of geographic information. The domain of a geographic information system is truly two-dimensional and it is necessary to compute, interpret, describe and analyze within this two-dimensional structure. It does not follow that two-dimensional problems require a two-dimensional method of solution, although it is rather firmly established that conventional one-dimensional approaches fail to give acceptable solutions to many spatial problems. For example, Unger[1] notes that "there are certain tasks, which might be termed spatial problems, at which digital computers are relatively inept ... pattern recognition is another area in which present day machines cannot match the performance of the designers." Solutions to two-dimensional problems may only require bigger and faster machines, but our analysis of the structure of maps suggests this is not the basic need. We, and other researchers concerned with two-dimensional structures, have reached the conclusion

[1]Unger, S. H. 1958. A computer oriented toward spatial problems, Proceedings of the IRE, 1745-1750.

that some type of two-dimensional language is required for description and analysis. Narasimhan[1] states:

> ... it is much more appropriate to view the so called pattern recognition problem as really the problem of pattern analysis and description and emphasize that the aim of any adequate recognition procedure should not be merely to derive a 'yes,' 'no,' or 'don't know' decision but to produce a structured description of the input picture. It is our contention that no model can hope to accomplish this in any satisfactory way unless it has built into it, in some sense, a generative grammer for the class of patterns it is set up to analyze and recognize.

The work by Kirsch[2] and his colleagues at the National Bureau of Standards also emphasizes two-dimensional syntactic structure for the description and analysis of pictorial sources. The University of Illinois group is motivated primarily by the analysis of bubble chamber photographs, the work at the National Bureau of Standards is motivated by the need to process schematics and diagrams in patent applications, whereas our work has been largely motivated by cartographic representations and, more generally, the structure of geographic information systems. Bubble chamber photographs, diagrams and maps are three kinds of pictorial sources and the recognition of a basic approach to the analysis of their two-dimensional structures is not surprising.

It is only recently that the study of two-dimensional languages has progressed from discussion of the need for such languages to the demonstration of partially convincing results. Two-dimensional syntactic structures have been obtained thus far only for pictorial sources substantially less complicated than required for the most simplified geographic information system. Though research in many directions is

---

[1] Narasimhan, R. 1964. Labeling schemata and syntactic descriptions of pictures, Information and Control, 7, 151-179.

[2] Kirsch, A. 1964. Computer interpretation of English text and picture patterns, I.E.E.E. Trans., EC-13, 363-376.

prerequisite to a viable geographic information system, our research has concentrated on only several of the topics believed critical to its eventual design and construction.

One research effort is predicted on the premise that maps and other cartographic devices are used for many purposes with high levels of efficiency and low levels of ambiguity. However, there is no theory of cartography and no serious attempt has been made to state the principles underlying the construction and use of maps. Maps and the uses of maps are now being studied to determine the principles, rules and procedures underlying map making and map use. It is believed that the recognition and isolation of elements of two-dimensional structures will be facilitated by this pragmatic analysis of maps.

Several formal one-dimensional languages have been formulated for space and space-time systems.[1] Though these languages do not satisfy our need for a two-dimensional syntax, the relevance of these spatially oriented languages to the description and analysis of two-dimensional sources is being analyzed. Special emphasis has been placed on the ten levels of semantic designation for space-time languages identified by Carnap and the principles of semiotic given initially by Morris.[2] It is anticipated that the results of this analysis will provide a useful basis for the formulation of a truly two-dimensional language.

---

[1]Carnap, R. 1958. Introduction to Symbolic Logic and Its Applications, New York: especially pp. 157-167.

Wilson, N. L. 1955. Space, time and individuals, Journal of Philosophy, 52, 589-598.

[2]Morris, C. W. 1938. Foundations of the theory of signs, Encyclopedia of Unified Science, 1.

_____. 1946. Signs, Languages and Behavior, New York.

Systems Modeling

At the start of this note, two areas (spatial statistics and spatial languages) were identified as being of fundamental importance to the deisgn and operation of a geographic information system. The identification of such critical subareas within the overall system is one of the goals of general system modeling. Before efficient development of a geographic information system can take place, the components of the systems must be specified and the nature of the complex net of interrelationships which link them must be clearly defined. Work on such a general systems model of a geographic information system has been begun and its completion is a necessary part of the developmental process leading to the construction and operation of a viable information system oriented toward spatial data.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Department of Geography Northwestern University Evanston, Illinois 60201	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

SOME COMMENTS ON CERTAIN TECHNICAL ASPECTS OF GEOGRAPHIC INFORMATION SYSTEMS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Technical Report

5. AUTHOR(S) *(Last name, first name, initial)*

Dacey, Michael F. and Duane F. Marble

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1965	10	7

8a. CONTRACT OR GRANT NO. Nonr 1228 (35) b. PROJECT NO. c. Task No. 389-142 d.	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Report No. 2 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. AVAILABILITY/LIMITATION NOTICES

"Distribution of this Document is Unlimited"

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Geography Branch Office of Naval Research

13. ABSTRACT

This document is intended to serve as a general preface to subsequent project reports of a more technical and specialized nature. Specialcattention is directed toward the work being carried on in the areas of spatial statistics and two-dimensional languages, and the relevance of this work to the development of generalized geographic information systems.

DD FORM 1 JAN 64 1473

Security Classification

"A" LIST

DIRECTOR
RESOURCE DEVELOPMENT ECONOMICS DIVISION
ECONOMIC RESEARCH SERVICE
U.S. DEPARTMENT OF AGRICULTURE
WASHINGTON 25, D. C.

COMMANDING OFFICER
AIR FORCE CAMBRIDGE RESEARCH LABORATORIE
ATTN CARLTON E. MOLINEUX
TERRESTRIAL SCIENCES LABORATORY
LAURENCE G. HANSCOM FIELD
BEDFORD, MASSACHUSETTS 01731

CENTRAL INTELLIGENCE AGENCY
ATTENTION OCR/DD-PUBLICATIONS
WASHINGTON, D. C. 20505

DEFENSE DOCUMENTATION CENTER
CAMERON STATION
ALEXANDRIA, VIRGINIA 22314

GEOGRAPHY DIVISION
BUREAU OF THE CENSUS
WASHINGTON 25, D. C.

SCIENCE AND TECHNOLOGY DIVISION
LIBRARY OF CONGRESS
WASHINGTON, D. C. 20540

DIRECTOR
NATIONAL OCEANOGRAPHIC DATA CENTER
WASHINGTON 25, D. C.

CHIEF OF NAVAL OPERATIONS /OP 922 V /
DEPARTMENT OF THE NAVY
WASHINGTON 25, D. C.

CHIEF OF NAVAL OPERATIONS /OP 922 Y1 /
DEPARTMENT OF THE NAVY
WASHINGTON 25, D. C.

CHIEF OF NAVAL OPERATIONS /OP 07T
DEPARTMENT OF THE NAVY
WASHINGTON 25, D. C.

COMMANDING OFFICER
U.S. NAVAL RECONNAISSANCE AND TECHNICAL
SUPPORT CTRE.
4301 SUITLAND ROAD
WASHINGTON 25, D. C.

THE OCEANOGRAPHER
U.S. NAVY OCEANOGRAPHIC OFFICE
WASHINGTON 25, D. C.

U.S. NAVY OCEANOGRAPHIC OFFICE
CODE 5005
WASHINGTON 25, D. C.

OFFICE OF NAVAL RESEARCH
CODE 131
WASHINGTON, D. C.

CHIEF OF NAVAL RESEARCH/CODE 437
OFFICE OF NAVAL RESEARCH
WASHINGTON 25, D. C.

CHIEF OF NAVAL RESEARCH/CODE 461/
OFFICE OF NAVAL RESEARCH
WASHINGTON 25, D. C.

CHIEF OF NAVAL RESEARCH
ATTENTION GEOGRAPHY BRANCH
OFFICE OF NAVAL RESEARCH
WASHINGTON 25, D. C.

COMMANDING OFFICER
OFFICE OF NAVAL RESEARCH
NAVY NO. 100
FLEET POST OFFICE
NEW YORK, NEW YORK

COMMANDING OFFICER
OFFICE OF NAVAL RESEARCH BRANCH OFFICE
219 SOUTH DEARBORN STREET
CHICAGO, ILLINOIS 60604

DIRECTOR, NAVAL RESEARCH LABORATORY
ATTENTION TECHNICAL INFORMATION OFFICER
WASHINGTON 25, D. C.

DR. H. HOMER ASCHMANN
DIVISION OF SOCIAL SCIENCE
UNIVERSITY OF CALIFORNIA
RIVERSIDE, CALIFORNIA

DR. PETER C. BADGLEY
OFFICE OF APOLLO APPLICATIONS
NASA HEADQUARTERS
WASHINGTON, D. C. 20546

MR. WALTER H. BAILEY
EARTH SCIENCES DIVISION
NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL
WASHINGTON, D. C. 20418

DR. CHARLES C. BATES
ASSISTANT CIVILIAN DIRECTOR
U.S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C. 20390

DR. JOHN R. BORCHERT
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MINNESOTA

DR. LEONARD W. BOWDEN
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF CALIFORNIA
RIVERSIDE, CALIFORNIA

MR. LAWRENCE BROWN
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF IOWA
IOWA CITY, IOWA

DR. REID A. BRYSON
DEPARTMENT OF METEOROLOGY
UNIVERSITY OF WISCONSIN
MADISON 6, WISCONSIN

MR. ANTHONY J. CALIO
NASA HEADQUARTERS
CODE SM
WASHINGTON D. C. 20546

DR. DOUGLAS B. CARTER
DEPARTMENT OF GEOGRAPHY
SOUTHERN ILLINOIS UNIVERSITY
CARBONDALE, ILLINOIS

MR. LEO CHILDS
CODE EX-24
NASA MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

DR. SAUL B. COHEN
DEPARTMENT OF GEOGRAPHY
CLARK UNIVERSITY
WORCESTER, MASSACHUSETTS 01610

DR. ROBERT N. COLWELL
DEPARTMENT OF FORESTRY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

DR. JOHN A. D. COOPER
DEAN OF SCIENCES
NORTHWESTERN UNIVERSITY
EVANSTON, ILLINOIS 60201

DR. RUTH M. DAVIS
OFFICE OF DIRECTOR OF DEFENSE
RESEARCH AND ENGINEERING
DEPARTMENT OF DEFENSE
WASHINGTON 25, D. C.

JOHN E. DORNBACH
CHIEF, LUNAR SPACE RESEARCH
TECHNOLOGY BRANCH
CODE ET-33
NASA MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 20770

DR. EDWARD B. ESPENSHADE
DEPARTMENT OF GEOGRAPHY
NORTHWESTERN UNIVERSITY
EVANSTON, ILLINOIS

MR. WILLIAM FISCHER
U.S. GEOLOGICAL SURVEY
WASHINGTON, D. C. 20242

PROFESSOR ROLAND FUCHS
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF HAWAII
HONOLULU, HAWAII 96822

MR. STEVEN B. GAWARECKI
ROOM 1243 A
G.S.A. BUILDING
18th AND E STREETS, N.W.
WASHINGTON, D. C.

DR. ARCH C. GERLACH
CHIEF, NATIONAL ATLAS PROJECT
TOPOGRAPHIC DIVISION
U.S. GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

CHARLES M. GRANT, JR.
ASST. FOR TECHNICAL INFORMATION
NASA MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 20770

DR. TORSTEN HAGERSTRAND
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF LUND
LUND, SWEDEN

DR. HARVEY HALL
CODE MTX
NASA HEADQUARTERS
WASHINGTON, D. C. 20546

DR. CHARLES B. HITCHCOCK
AMERICAN GEOGRAPHICAL SOCIETY
BROADWAY AT 156th STREET
NEW YORK, 32, NEW YORK

MR. M. R. HOLTER
INFRARED AND OPTICAL SENSOR LABORATORY
INSTITUTE OF SCIENCE AND TECHNOLOGY
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN 48103

DR. EDGAR M. HORWOOD
121 MORE HALL
UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON

MR. CHARLES HUEBNER
CODE MTE
NATIONAL AERONAUTICS AND SPACE
ADMINISTRATION
WASHINGTON, D. C. 20546

PROF. WALTER ISARD
DEPARTMENT OF REGIONAL SCIENCE
WHARTON SCHOOL
UNIVERSITY OF PENNSYLVANIA
PHILADELPHIA, PENNSYLVANIA 19104

ALLAN KOVER
REGIONAL GEOPHYSIC BRANCH
U.S. GEOLOGICAL SURVEY
WASHINGTON, D. C. 20242

DR. WILLIAM KRUMBEIN
DEPARTMENT OF GEOLOGY
NORTHWESTERN UNIVERSITY
EVANSTON, ILLINOIS 60201

DR. JAMES P. LATHAM
PROFESSOR AND CHAIRMAN OF GEOGRAPHY
FLORIDA ATLANTIC UNIVERSITY
BOCA RATON, FLORIDA

DR. ROGER A. LEESTMA
U.S. ARMY ENGINEER/GIMRADA/
GEOGRAPHIC INTELLIGENCE DIVISION
FT. BELVOIR, VIRGINIA 22060

DEAN SIMEON E. LELAND
COLLEGE OF ARTS AND SCIENCES
NORTHWESTERN UNIVERSITY
EVANSTON, ILLINOIS

DR. R. J. P. LYON
DEPARTMENT OF GEOPHYSICS
STANFORD UNIVERSITY
STANFORD, CALIFORNIA

DR. AKIN MABOGUNJE
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF IBADAN
IBADAN, NIGERIA

PROFESSOR J. ROSS MACKAY
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF BRITISH COLUMBIA
VANCOUVER, BRITISH COLUMBIA, CANADA

DR. MARION E. MARTS
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF WASHINGTON
SEATTLE 5, WASHINGTON

DR. ROBERT C. MAYFIELD
GEOGRAPHY DEPARTMENT
UNIVERSITY OF TEXAS
AUSTIN, TEXAS

O. M. MILLER
AMERICAN GEOGRAPHICAL SOCIETY
BROADWAY AT 156th STREET
NEW YORK, NEW YORK 10032

DR. RICHARD L. MORRILL
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF WASHINGTON
SEATTLE 5, WASHINGTON

MR. ALASTAIR MORRISON
DEPARTMENT OF GEOGRAPHY
MCGILL UNIVERSITY
MONTREAL, QUEBEC, CANADA

DR. WILLIAM NORDBERG
NASA GODDARD SPACE FLIGHT CENTER
CODE 651
GREENBELT, MARYLAND

PROFESSOR JOHN D. NYSTUEN
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

MR. ROBERT W. PEPLIES
DIRECTOR OF RESEARCH
EAST TENNESSEE STATE UNIVERSITY
JOHNSON CITY, TENNESSEE

DR. WILLARD J. PIERSON
DEPARTMENT OF METEOROLOGY AND
OCEANOGRAPHY
NEW YORK UNIVERSITY
SCHOOL OF ENGINEERING AND SCIENCE
UNIVERSITY HEIGHTS
BRONX 53, NEW YORK

PROFESSOR FORREST R. PITTS
SOCIAL SCIENCE RESEARCH INSTITUTE
2550 CAMPUS ROAD
UNIVERSITY OF HAWAII
HONOLULU, HAWAII 96822

DR. LEWIS T. REINWALD
10002 CEDAR LANE
KENSINGTON, MARYLAND

MR. AZRIEL ROSENFELD
COMPUTER SCIENCE CENTER
UNIVERSITY OF MARYLAND
COLLEGE PARK, MARYLAND 20742

DR. RICHARD J. RUSSELL
COASTAL STUDIES INSTITUTE
LOUISIANA STATE UNIVERSITY
BATON ROUGE 3, LOUISIANA

MR. BERNARD B. SCHEPS
U.S. ARMY ENGINEER/GIMRADA/
FT. BELVOIR, VIRGINIA 22060

DR. JOHN C. SHERMAN
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF WASHINGTON
SEATTLE 5, WASHINGTON

DR. DAVID S. SIMONETT
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF KANSAS
LAWRENCE, KANSAS

DR. WILBUR A. STEGER
CONSAD RESEARCH CORPORATION
3406 FIFTH AVENUE
PITTSBURGH 13, PENNSYLVANIA 15213

DR. DIETER STEINER
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF ZURICH
FREISTRASSE 30
ZURICH 32, SWITZERLAND

PROFESSOR EDWARD J. TAAFFE
DEPARTMENT OF GEOGRAPHY
THE OHIO STATE UNIVERSITY
COLUMBUS 10, OHIO

DR. WALDO R. TOBLER
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

ROGER TOMLINSON
DEPARTMENT OF FORESTRY
VICTORIA BUILDING
WELLINGTON STREET
OTTAWA, ONTARIO

WILLIAM WARNTZ
AMERICAN GEOGRAPHICAL SOCIETY
BROADWAY AT 156th STREET
NEW YORK, NEW YORK 10032

MR. RICHARD H. WILCOX
INFORMATION SYSTEMS BRANCH
OFFICE OF NAVAL RESEARCH
WASHINGTON, D.C. 20360

DR. M. GORDON WOLMAN
DEPARTMENT OF GEOGRAPHY
JOHNS HOPKINS UNIVERSITY
BALTIMORE 18, MARYLAND