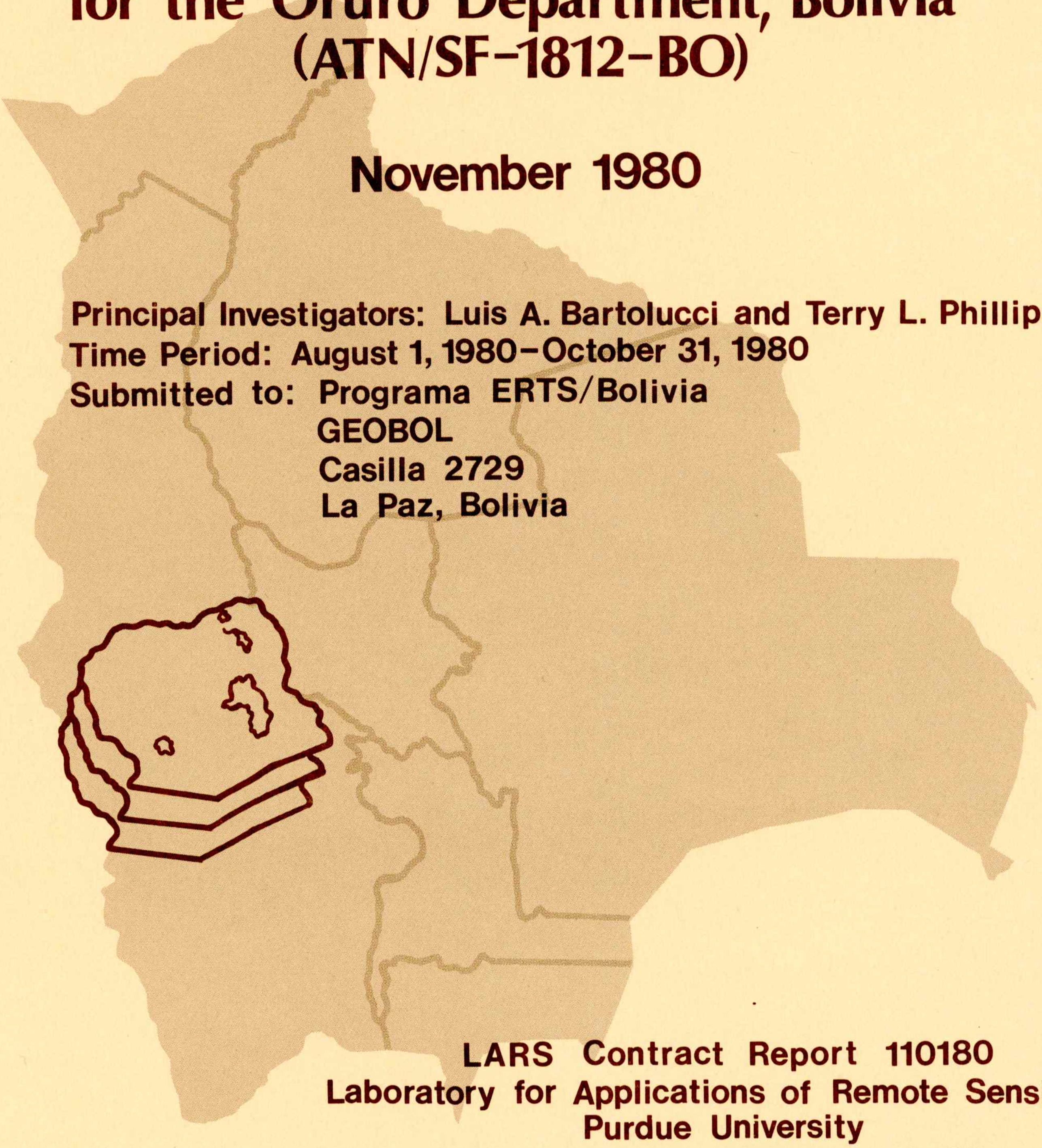
Quarterly Progress Report

Digital Information System for the Oruro Department, Bolivia

(ATN/SF-1812-BO)



November 1980

Principal Investigators: Luis A. Bartolucci and Terry L. Phillips
Time Period: August 1, 1980–October 31, 1980
Submitted to: Programa ERTS/Bolivia
GEOBOL
Casilla 2729
La Paz, Bolivia

LARS Contract Report 110180
Laboratory for Applications of Remote Sensing
Purdue University
West Lafayette, Indiana 47906
USA

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Oruro Department, Bolivia (ATN/SF-1812-BO)

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Terry L. Phillips
Purdue University/LARS
1220 Potter Drive
West Lafayette, Indiana 47906
USA

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INTRODUCTION

Background

Basic information on the location, quantity and availability of the natural resources of a region is indispensable for planning more rationally its development, use and/or conservation. The degree of usefulness of this information to planners and decision makers depends on the degree of accessibility and efficiency of the methods utilized for input, storage and retrieval of information.

As new advances in aerospace remote sensing technology make possible the gathering of large quantities of information on natural resources over extended geographical areas, more effective procedures for inputting, storing and retrieving this information need to be developed.

Parallel advances in digital computer technology provide the basic capability for designing and implementing an integrated information system that can meet the requirements for more effective procedures to input store, process, and retrieve natural resource information.

Objective

The main objectives of this effort are to:

1. Design an integrated information system for the natural resources of Bolivia, and
2. Test the feasibility of this design using data from the Oruro Department.

According to the contract between the Programa ERTS/Bolivia (ERTS GEOBOL) and Purdue University (Purdue Research Foundation), this project will have a duration of 18 months starting on the date of final execution of this contract. The contract was signed by the Director of the Programa ERTS on July 28, 1980, by a Purdue official on August 14, 1980, and by the Deputy Director of GEOBOL on September 5, 1980.

Although the signed contract was received at Purdue University on September 16, 1980 (PST/A/946/80), several technical tasks of this project had been accomplished before September 16, 1980, which include:

1. Definition of a project implementation plan
2. Survey of the literature
3. Preparation of a system design draft
4. Selection of an optimum map projection
5. Specification of the Landsat digital mosaic
6. Assessment of geocoding alternatives
7. Selection of criteria for input channels
8. Discussions with Bolivian technical personnel

PROJECT IMPLEMENTATION PLAN

The proposed project implementation plan is shown in Figure 1. All the tasks scheduled for the period before August 1, 1980 were completed on time. This plan was submitted to the Director of the Programa ERTS on July 24, 1980 and it was subsequently approved by the Bolivian officials on August 1, 1980.

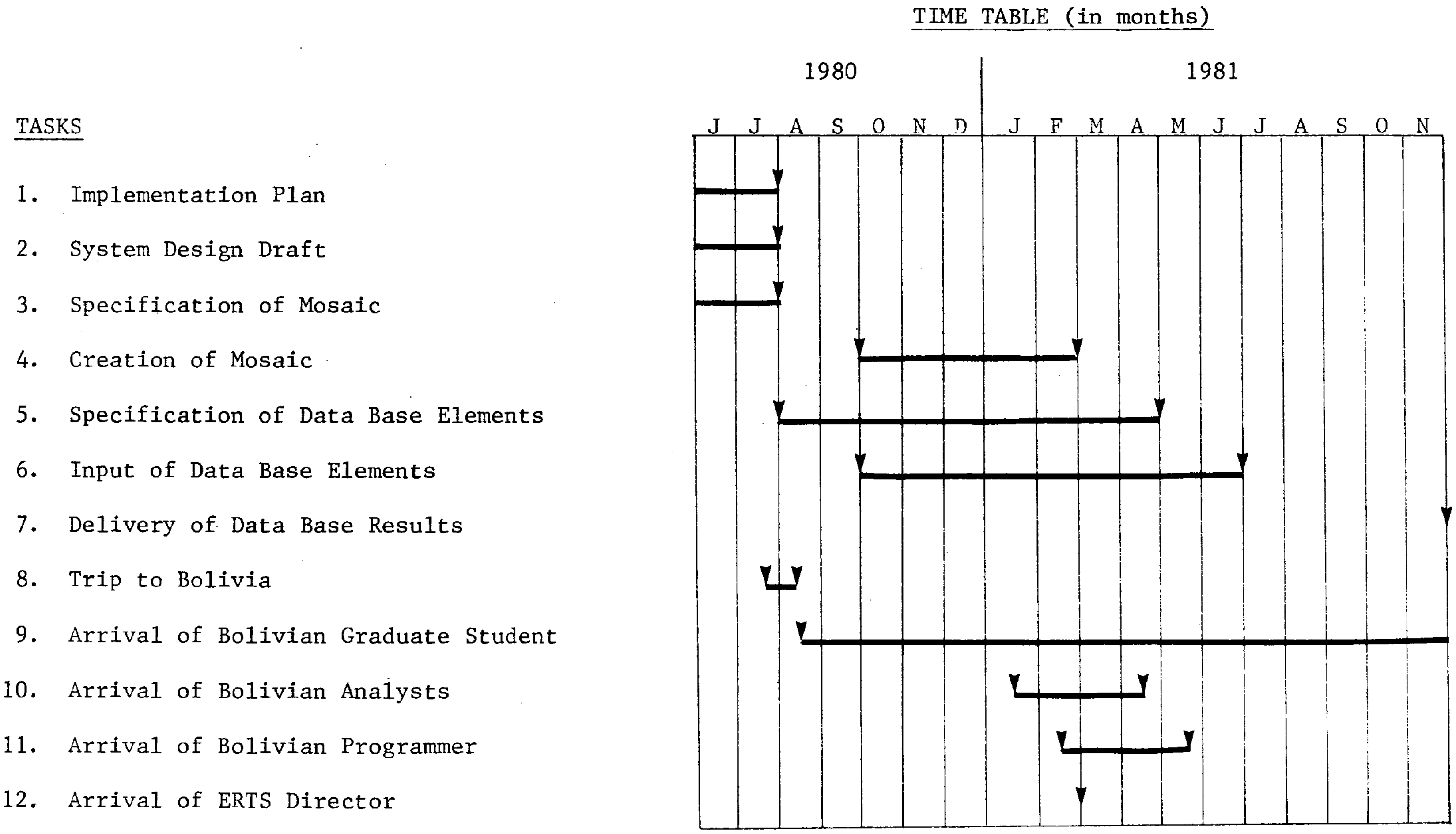

Figure 1. Proposed project implementation plan (as of July 1, 1980).

SURVEY OF THE LITERATURE

In order to be able to answer some basic questions regarding the design of a digital geographic information system for Bolivia, a preliminary review of the available literature on this subject was conducted. A list of the reviewed publications is included in Appendix A of this report. A number of these publications have been summarized and are presented in the following pages.

Billingsley, Frederic C., and Bryant, Nevin A., "Design Criteria for a Multiple Input Land Use System", NASA Earth Resources Survey Symposium Proceedings, Vol. 1, pt. 2, 1975.

Abstract

Polygon overlay and grid cell information systems access data for selected areas, but their data files are time consuming to generate and frequently costly to process. A design is presented that proposes the use of digital image processing techniques to interface existing data sets and information management systems with thematic maps and remotely sensed imagery. The basic premise is that geocoded data sets can be referenced to a raster scan that is equivalent to a grid cell data set, and that images taken of thematic maps or from remote sensing platforms can be converted to a raster scan. A major advantage of the raster format is the x, y coordinates are implicitly recognized by their position in the scan, and z values can be treated as Boolean layers in a three dimensional data space, permitting rapid comparison of data sets and adaptation to variable scales.

Bryant, Nevin A., and Zobrist, Albert L., "An Image-Based Information System: Architecture for Integrating Satellite Imagery and Cartographic Data Bases", JPL/Caltech, Pasadena, California.

Abstract

The initial reasons for the development of the IBIS (Image-Based Information System) was to allow the processing of a Landsat thematic map showing land use or land cover in conjunction with a census tract polygon file to produce a tabulation of land use acreages per census tract. From the study, it was found that a large number of image processing and data manipulation capabilities would be needed for even the simplest case, and that with proper design, the system could be extended into a general information system with new features and capabilities. The discussion centers on the capabilities of IBIS, requirements for implementation, and a Orlando, Florida test case demonstrating the integration of 1970 census data and 1975 Landsat land use data.

Cicone, Richard C., "Remote Sensing and Geographically Based Information Systems", in Proceedings of the 11th International Symposium on Remote Sensing of Environment, Vol. 2, 1977.

Abstract

The paper reviews some conepts that distinguish geographic information systems and proposes a simple model which can serve as a conceptual framework for the design of a genralized geographical information system. The discussion highlights system characteristics and needs involving data specification, acquisition, management and processing.

Dueker, Kenneth J., "A Framework for Encoding Spatial Data", Geographical Analysis, Vol. 4, 1972, pp. 98-105.

Abstract

Alternative methods for encoding geographic patterns are proposed by, 1) development of a methodology in converting geographic data to machine-readable form, and 2) presentation of a notation for use in this conversion process.

Dueker, Kenneth J., "Cartographic Data Structures: Alternatives for Geographic Information Systems", Computer Graphics, Vol. 10, No. 2, Summer, 1976.

Abstract

The first section of this paper discusses options for methods in encoding geographic data. Encoding, formatting, storage, and output of data are related by analogy to information theory. The paper attempts to 1) identify the potential for error in data encoding so that system designers can be alert to these situations and make allowances, and 2) present effective measures and means to compare different systems.

Edson, Dean T., and Lee, George, "Ways of Structuring Data Within a Digital Cartographic Data Base", Computer Graphics, Vol. 11, No. 2, Summer 1977, pp. 148-157.

Abstract

The paper presents some ideas about structuring the components of a digital cartographic data base (DCDB). The U.S. Geological Survey is developing a DCDB within the National Mapping Program to include such features and reference systems as the public land survey network, state and county boundaries, transportation systems, and hydrography. Such data included in a DCDB have no legal status and are intended for display and map reference only. The interrelationships of these components requires care in structuring the digitized data so that valuable time is not wasted in producing cartographic spaghetti.

Hardy, Ernest E., "The Design, Implementation, and Use of a Statewide Land Use Inventory: The New York Experience", NASA Earth Resources Survey Symposium Proceedings, Vol. 1, pt. 3, 1975.

Abstract

A review of the design, management, and application of the New York State computerized land use and natural resources inventory.

Hill, D.R., and Jefferson, R.F., "System Considerations for a Unified Cartographic Data Bank", Surveying and Mapping, Vol. 29, 1969, pp. 485-492.

Abstract

The software functions necessary to support a unified cartographic/land use data bank are emphasized and currently existing technologies are described. Data organization, storage, retrieval, and output are discussed.

Kennedy, Michael, and Meyers, Charles R., "Spatial Information Systems: An Introduction", Louisville: Urban Studies Center, 1975.

Abstract

This book takes a comprehensive look at the methodologies, equipment, and infrastructure of spatial information systems. Much of the material is oriented from the standpoint that spatial information systems will be developed by governmental organizations no smaller than states. The discussion approaches six aspects of spatial information systems: 1) Decision Making and its Basis, 2) Potential Uses for a Spatial Information System, 3) How to Determine the Needs for Information, 4) Information as a Product, 5) Data as Raw Material, and 6) The Ingredients of a Spatial Information System.

Knapp, Ellen M., and Rider, Deborah, "Automated Geographic Information Systems and Landsat Data: A Survey", in Harvard Computer Graphics Week, Proceedings of an International User's Conference on Computer Mapping Software and Data Bases: Applications and Dissemination, Harvard University, Cambridge, Massachusetts, July 23-28, 1978.

Abstract

This paper summarizes a study conducted by Computer Sciences Corporation of automated geographic information systems (GIS) technology. The paper reviews the state-of-the-art of GIS technology, examines the possibility and usefulness of inputting Landsat data to a automated GIS, and surveys and analyzes a variety of GIS software.

Moik, Hans G., "A Data Base Management System for Remote Sensing Data", in Harvard Computer Graphics Week, Proceedings of an International User's Conference on Computer Mapping Software and Data Bases: Application and Dissemination, Harvard University, Cambridge, Massachusetts, July 23-28, 1978.

Abstract

This is a case study of an integrated data base management system developed at the NASA/Goddard Space Flight Center to support its application research activities. Common to many of the research activities is the need to combine and spatially overlay data from different sensors taken at different times, in different wavelengths, and with varying spatial and temporal resolutions. Thus, the available data represent spatially distributed data, point measurements, graphs, or text. The report looks at the data base system requirements, the structure of and integrated data base management system, and operation of the system.

Powers, M.W., "Computerized Geographic Information Systems: An Assessment of Important Factors in Their Design, Operation, and Success", Center for Development Technology, Washington University, St. Louis, Missouri, December, 1975.

Abstract

This report is a comprehensive analysis of computerized geographic information systems. Such major design issues as user needs, georeferencing and geocoding, accessing methods, data accuracy, and system capabilities are inspected. Thirty different systems are described, analyzed, and compared as to their organization, capabilities, quality of output, cost, marketabilities, and user satisfaction. General observations and conclusions are drawn. An idealized geographic information system is described and future development needs are briefly outlined.

Steiner, D., "Remote Sensing and Spatial Information Systems", Approaches to Earth Survey Problems Through Use of Space Techniques, COSPAR, Proceedings of the Symposium held in Konstance, F.R.G. 23-25 May, 1973, Akademie-Verlag, Berlin, 1974.

Abstract

The paper is essentially a review of the results of the 1967 and 1972 IGU meetings of the Commission on Geographical Data Sensing and Processing. It looks at the possibilities and problems of integrating remote sensing data into spatial information systems. Processes such as data specification, acquisition, input, storage, processing and output are discussed, followed by an examination of the special problems involved in the use of remote sensing data.

Zobrist, Albert L., and Bryant, Nevin A., "Elements of an Image-Based Information System", Proceedings Caltech/JPL Conference on Image Processing Technology, Data Sources and Software for Commercial and Scientific Applications, California Institute of Technology, Pasadena, California, November 3-5, 1977.

Abstract

The purpose of this report is to describe the functional requirements and system for the Image-Based Information System (IBIS) developed at the Jet Propulsion Laboratory. The IBIS system extends the capability of present systems by adding a new data-type, the image raster, in such a way that it can be used with tabular data bases. Until recently, the image format has been used primarily as a computer processable equivalent of a photo, with the value stored in each cell of the image representing a shade of grey or color. If the image is of a geographical area, then the value in a cell can be a datum for the area corresponding to the cell. A major advantage of the image representation is that data for a geographical point can be accessed immediately by position in the image matrix. This report describes an advanced test case in Portland, Oregon.

Bryant, N.A., and Zobrist, A.L., "IBIS: A Geographic Information System Based on Digital Image Processing and Image Raster Data Type", IEEE Transactions on Geoscience Electronics, Vol. GE-15, No. 3, July 1977, pp. 152-159.

Abstract

A description of the IBIS geographic information system, with test cases in Louisiana and Los Angeles, California.

Peuker, Thomas K., and Chrisman, Nicholas, "Cartographic Data Structures", The American Cartographer, Vol. 2, No. 1, April 1975, pp. 55-69.

Abstract

Most current data banks are characterized by 1) structures which are convenient at the input stages of use within computer programs, 2) separate and uncoordinated files for different types of geographic features, and 3) a lack of information about neighboring entities. This paper characterizes existing geographic and cartographic data systems for planar and three-dimensional surfaces with respect to these three problems. It describes attempts which have been made by the authors to produce data systems which eliminate some of the problems of existing ones. The term "neighborhood function" is introduced, defined, and described in relation to the GEOGRAF system for encoding planar data and the GDS ("Geographic Data Structure") for encoding three-dimensional surfaces.

Dangermond, J., "ESRI Geographic Information Software Descriptions", Environmental Systems Research Institute, Redlands, California.

Abstract

This report outlines the various programs contained within the ESRI software systems known as PIOS, GRID, and AUTOMAP. PIOS and AUTOMAP programs handle x,y coordinate data. The GRID system is designed for raster type information. The salesmanship-type approach of this report presents basic concepts of geo-information systems and the three ESRI systems structures and capabilities.

Dangermond, J., "A Sketchbook of Experiences: Geographic Information System", Environmental Systems Research Institute, Redlands, California.

Abstract

This sketchbook contains a series of graphic images showing the kinds of experiences which ESRI has had with the creation and use of geographic information systems. It is a user-oriented account of the systems and approaches which ESRI is currently marketing.

Tomlinson, R.F., (ed.) "Geographic Data Handling", Symposium Edition, 2 Volumes, International Geographical Union Commission on Geographical Data Sensing and Processing, Ottawa, 1972.

Abstract

These volumes represent the results of the working group activities toward describing the current state-of-the-art of geographical information systems, setting guidelines for future systems, and identifying needed research. It attempts to present a comprehensive review of the field of geographical information systems directed toward individuals and agencies who face decisions about the development or use of such systems. A broad range of topics are discussed in depth, ranging from basic considerations concerning data specification, acquisition and handling through spatial data manipulation and analysis to the concepts and methods of system design. Data collection by remote sensing automatic processing and classification of remote sensing data, input to information systems, equipment for spatial data processing, assessment of equipment systems, data display and its applications, automatic cartography, and the economics of geo-information systems are all discussed in detail. A representative number of geo-information systems are discussed.

SYSTEM DESIGN DRAFT

Data Storage

The digital Geographic Information System (GIS) proposed for Bolivia was designed by Mr. Terry L. Phillips and it consists basically of a four-level-16-element grid cell structure.

The grid cells are created by constructing a hypothetical plane of 1500 Kilometers in the horizontal (E-W) direction and 1500 Kilometers in the vertical (N-S) direction, thus forming a squared plane which contains the entire Bolivian territory. This plane is subdivided into 30,000 equal parts in both the horizontal and vertical directions, resulting in a total of 900 million cells representing squared areas on the earth surface of 50 meters by 50 meters each.

The data base will actually consist of a geometrically corrected Landsat digital mosaic, which will be constructed using Landsat Computer Compatible Tapes (CCT's) and appropriately selected ground control points of known geographic locations. Through a procedure of rubber sheet stretching and pixel (picture element) resampling the Landsat digital mosaic will be rectified to a desired map projection in order to attain cartographic accuracy.

The initial data base proposed for Bolivia would contain 16 elements or bytes of information per cell. Four of these elements would consist of the four Landsat MSS (multispectral scanner system) bands, and the other elements would contain other types of information, such as political boundaries, socio-economic data, natural resources information, etc. Using this design, there would be a storage requirement of 14,400,000,000 bytes of data. However, this storage requirement could be decreased using a more logical data management system, such as the subdivision of the entire data base plane (geo-referenced plane) into quadrants of 1000 by 1000 cells. Each of these quadrants would contain 16,000,000 bytes of data and could be stored in a single 800 bpi (bytes per inch) magnetic tape. Because of the shape of Bolivia with respect to the hypothetical 1500 Kilometer by 1500 Kilometer plane, several of these quadrants will not be used. Thus, the estimated number of quadrants that would cover the entire Bolivian territory is 492 as illustrated in Figure 2, and it would decrease the storage requirement to 7,872,000,000 bytes.

A data base consisting of 50 meter by 50 meter cells would be useful for data input procedures; however, it would not permit reasonable access to information at Departmental and National levels. The proposed solution to this problem is to design a hierarchical data base structure using four different levels of storage as indicated in Table 1.

The first level of storage, i.e., the 50 meter by 50 meter cell data base would be used for data input. The second level could be constructed by combining the information in the first level into 100 meter by 100 meter cells, thus creating 100 Kilometer by 100 Kilometer quadrants as shown in Figure 3.

A third data base level could be constructed from either levels 1 or 2 and it would consist of a 500 meter by 500 meter grid. The whole country would be covered by 9 quadrants. This data base would be useful for departmental studies (Figure 4).

A fourth data base level could be created also from either levels 2 or 3 and it would consist of a 1000 meter by 1000 meter grid. At this level Bolivia would be covered by a single 1300 Kilometer by 1500 Kilometer quandrant. Its purpose would be to provide effective access to information for national level studies. (Figure 5)

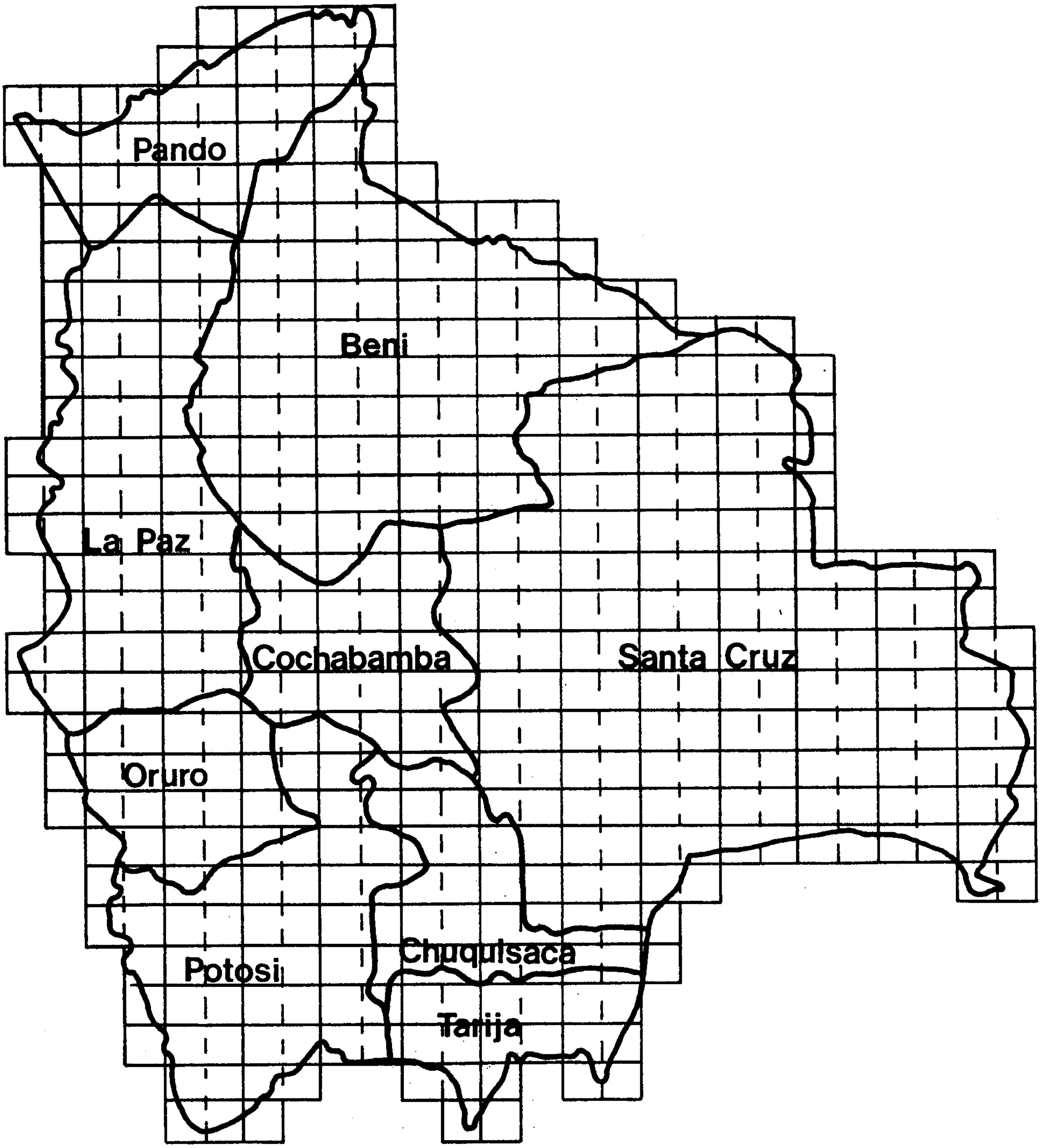

Figure 2. Level 1 data base showing 492 quadrants. Each quadrant covers a 50 x 50 Kilometer area.

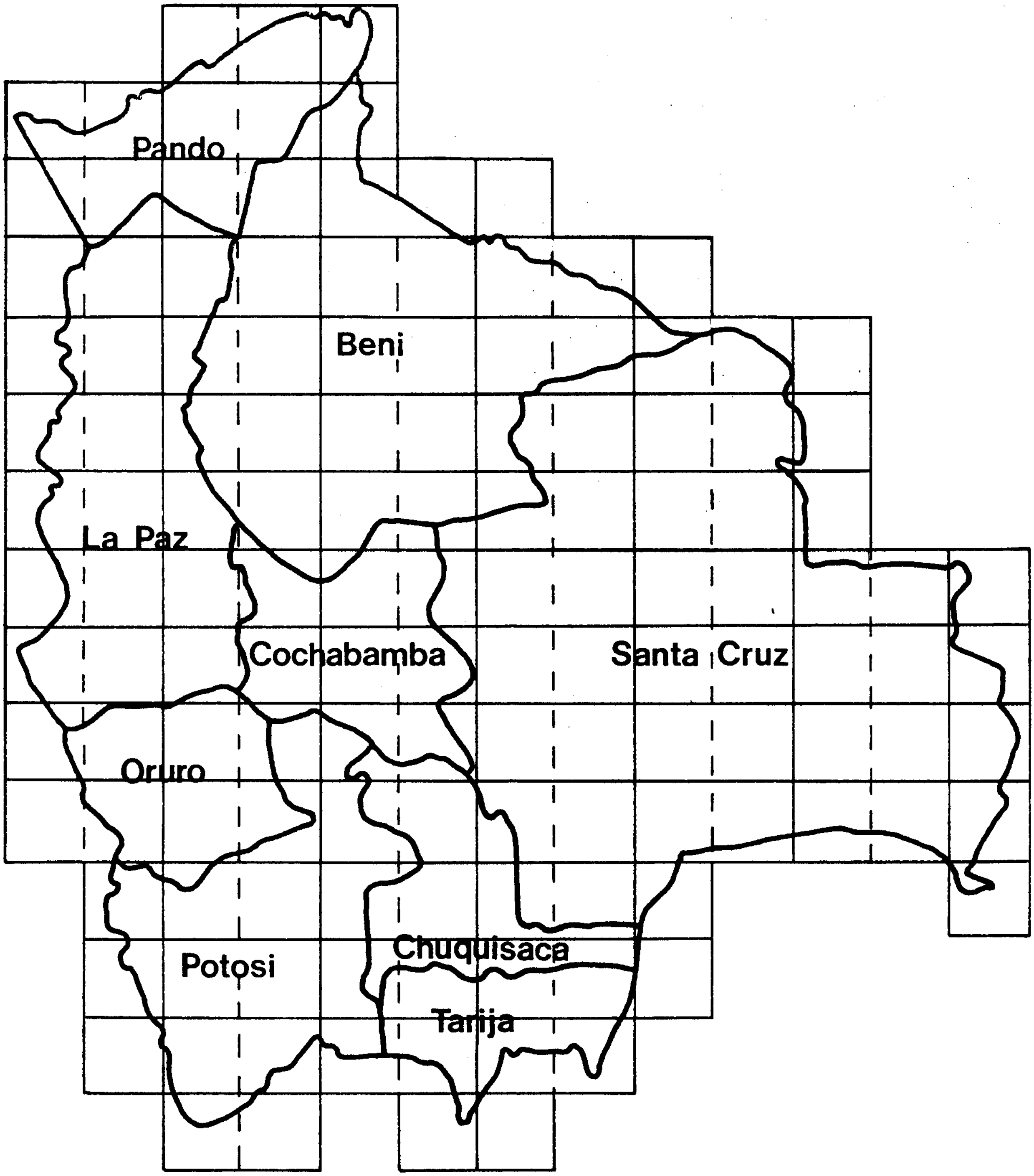

Figure 3. Level 2 data base showing 137 quadrants. Each quadrant covers a 100 x 100 Kilometer area.

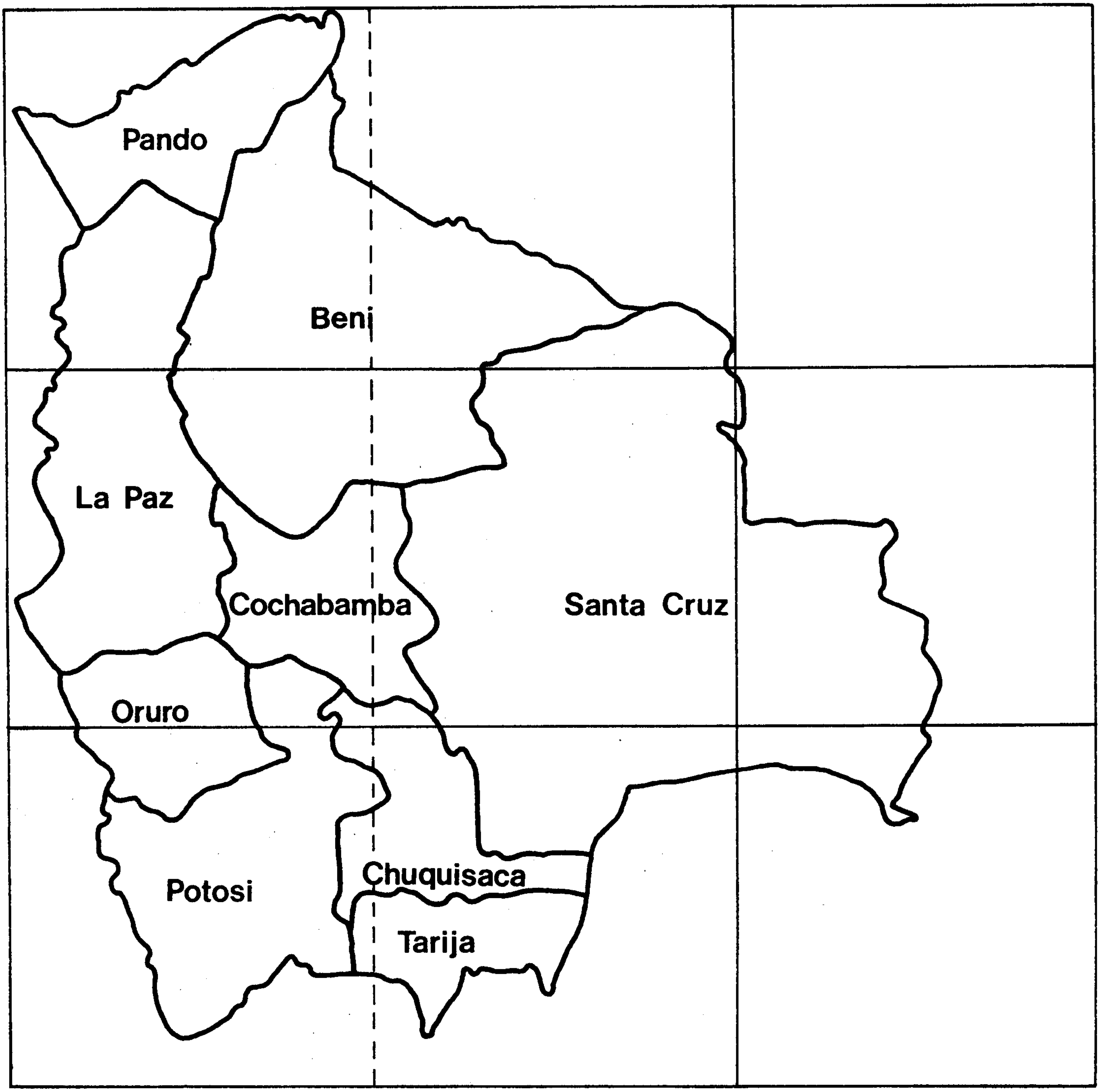

Figure 4. Level 3 data base showing 9 quadrants. Each quadrant covers a 500 x 500 Kilometer area.

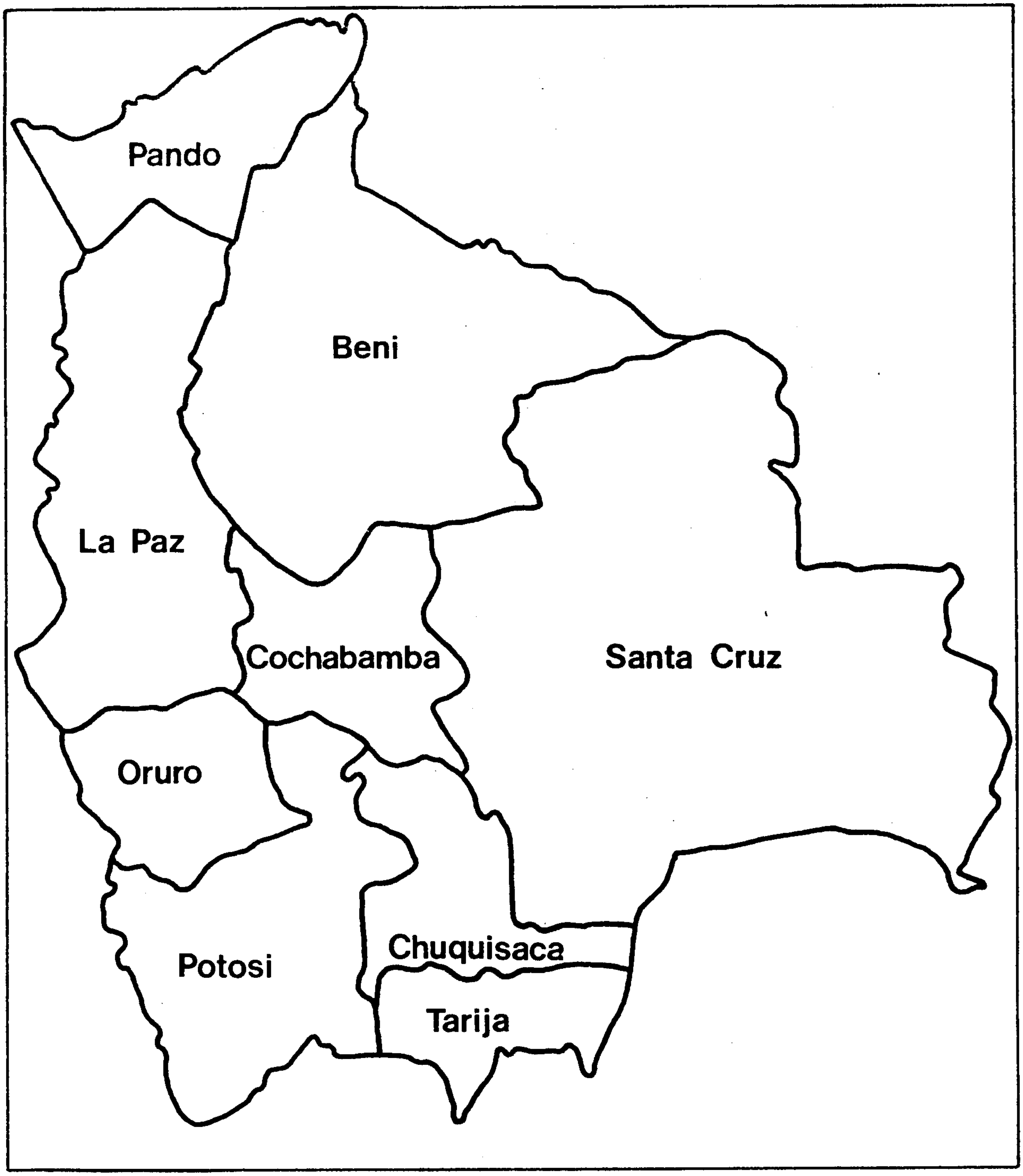

Figure 5. Level 4 data base showing a 1300 x 1500 Kilometer area.

Table 2 shows the characteristics of a hierarchical data base structure for the Oruro Department.

The four grid cell sizes (50 m, 100 m, 500 m, and 1000 m) that correspond to the four different data base levels (input, local, departmental, and national levels) were chosen from a data base alternative study. The results of this study are shown in Tables 1, 2, 3, and 4 of Appendix B.

Required Hardware

The hardware configuration ideally required to support a digital geographic information system for Bolivia is shown schematically in Figure 6.

SELECTION OF AN OPTIMUM MAP PROJECTION

Since one of the most important uses of a geographic information system is to determine areal extent of ground cover/land use information from data stored in a grid cell form, the selection of an equivalent (equal area) map projection becomes imperative. In an equivalent map projection, every data cell (pixel) represents the same area on the earth surface regardless of the cell position in the data base. In contrast, a conformal (equal form) map projection does not meet this requirement.

In order to choose the most suitable map projection for the Bolivian geographic information system, this projection would have to meet the following six requirements:

1. The map projection to be selected should be a projection in widespread use and relatively easy to compute.
2. The chosen projection should be suitable for the production of separate sheets which would fit accurately together into one whole map.

Storage Level	Purpose	Cell Size	Quadrant Size	No. of Quadrants Covering Bolivia	Bytes of Data for Bolivia
1	Input	50 m X 50 m	50 km X 50 km	492 (Figure 2)	$7,872 \times 10^6$
2	Local studies	100 m X 100 m	100 km X 100 km	137 (Figure 3)	$2,192 \times 10^6$
3	Departmental studies	500 m X 500 m	500 km X 500 km	9 (Figure 4)	144×10^6
4	National studies	1000m X 1000m	1300km X 1500km	1 (Figure 5)	31×10^6

Table 1. Hierarchical Data Base Structure for Bolivia.

Storage Level	Purpose	Cell Size	Quadrant size	No. of Quadrants Covering Oruro	Bytes of Data For Oruro
1	Input	50 m X 50 m	50 km X 50 km	33	528 X 10^6
2	Local studies	100 m X 100 m	100 km X 100 km	12	192 X 10^6
3	Departmental studies	500 m X 500 m	500 km X 500 km	2	32 X 10^6
4	National studies	1000m X 1000m	1300km X 1500km	--	----

Table 2. Hierarchical Data Base Structure for the Oruro Department.

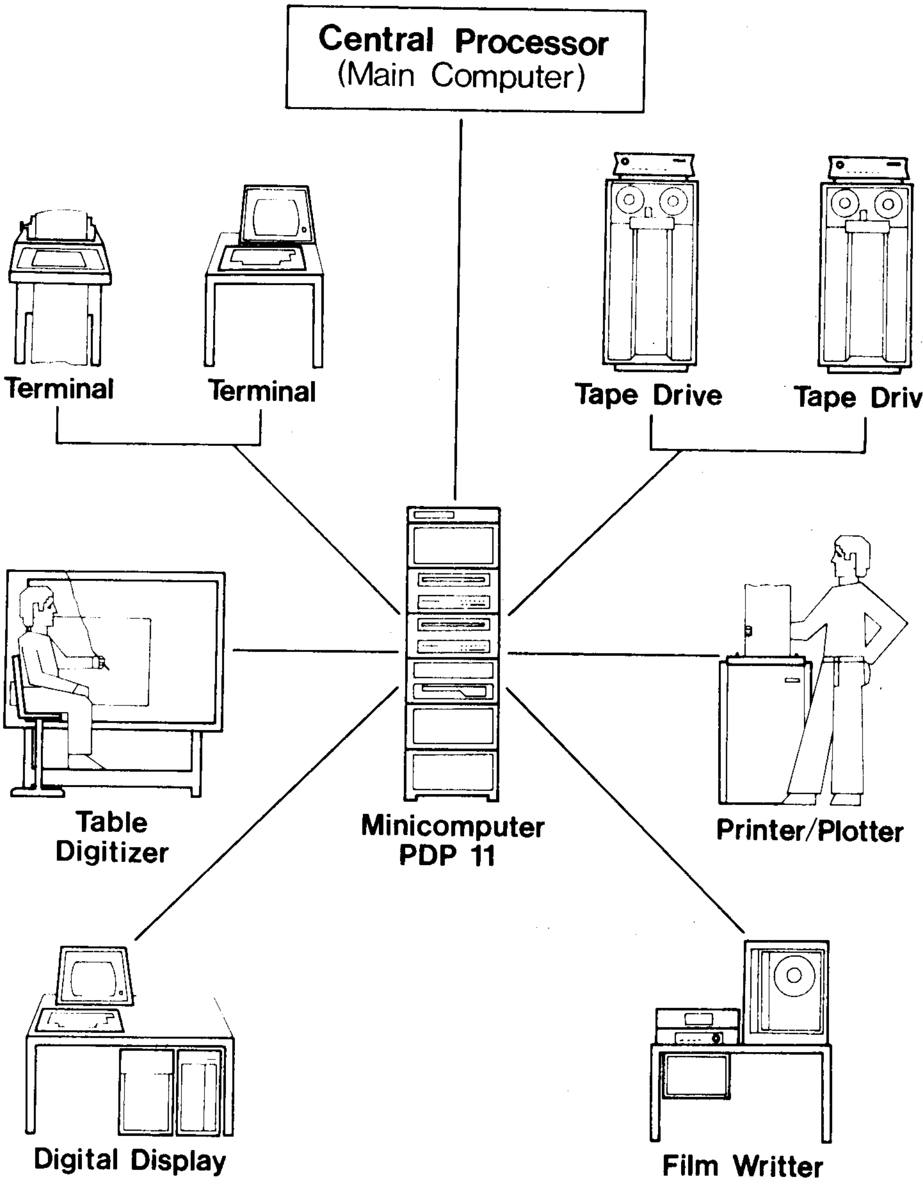

Figure 6. Schematic hardware configuration required to support a digital geographic information system.

3. The entire region to be mapped will be covered by a single projection suitable for representation at scales ranging from 1:25,000 to 1:1,000,000.
4. Scale error throughout the projection should be minimized.
5. Maximum error of area must be zero, enabling the use of projection-independent algorithms to compute areal estimates of ground cover.
6. Maximum error of aximuth should be minimized as much as possible.

A number of the most commonly used map projections were examined in the light of the six selection requirements. These map projections are:

1. Universal Tranverse Mercator-Conformal projection used primarily in military mapping at scales of 1:50,000 or larger.
2. Polyconic-Standard projection for field map at scales of 1:50,000 and larger. Predominate use is 1:24,000 quadrangle maps.
3. Lambert Conformal Conic-A conformal conical projection with two standard parallels.
4. Lambert Zenithal equal-area-A stereographic projection with a standard meridian and standard parallel.
5. Albers equal-area-An equivalent conic projection with two standard parallels.

Combining these five map projections with the six selection requirements, the following selection matrix was developed:

Projection	Requirements 1	2	3	4	5	6
1. UTM				X		X
2. POLYCONIC	X					
3. LAMBERT-CONF.	X	X	X			X
4. LAMBERT-ZEN.		X	X		X	X
5. ALBERS	X	X	X	X	X	X

The selection matrix shows that the Albers equal-area projection is the most suitable projection for a natual resources data base of Bolivia. The Albers projection has also other beneficial characteristics. Because this projection is developed from a conic surface using two standard parallels, it is very nearly conformal-in fact, a comparison between the Albers and Lambert conformal conic projections would show only slight differences. This map projection may also be subdivided into smaller sheets which later can be fit together exactly if desired.

The Albers equal-area projection to be used for constructing the geographic information system for Bolivia would need to cover from 8° S to 24° S in latitude, and 58° W to 70° W in longitude. 12° S and 20° S were chosen as the standard parallels and 64° W was chosen as the standard meridian.

The mathematical theory of the Albers map projection is described in detail in Deetz and Adams (1944). The procedure for calculating the Albers map projection for the Bolivian geographic information system is described in detail in the paper by Terry L. Phillips entitled "An Addressing Scheme for a Bolivian Natural Resources Data Base" (November 1980) which is included in Appendix C. This paper also contains a listing of the computer program (in BASIC language) which was developed to compute the Albers projection for Bolivia. A justification for selecting the Albers projection has been prepared by Ing. Oscar Torrez from the Programa ERTS/Bolivia and is included in Appendix D.

SPECIFICATIONS FOR A LANDSAT DIGITAL MOSAIC

As indicated previously, the geo-referenced standard data base plane for the Bolivian geographic information system will be created by mosaicking digitally Landsat MSS scenes. Two major reasons are behind the decision to use Landsat MSS data as the standard data base plane: 1) it provides (after conducting appropriate geometric rectifications) a cartographically accurate plane to which future remote sensing and ancillary data files can be registered with relative ease, and 2) it allows the user to interact visually (pictorial interphase) with the data base.

The Landsat digital mosaicking task for the Oruro Department will be performed by the Jet Propulsion Laboratory (JPL), California Institute of Technology, Pasadena, California, according to an agreement (JPL Task Plan No. 90-1470) with Purdue University's Laboratory for Applications of Remote Sensing. Under this agreement, JPL will use the VICAR/IBIS (Video Image Communication and Retrieval/Image Based Information System) software developed by JPL to create a multi-frame Landsat MSS digital mosaic of the Oruro Department. The specific tasks required from JPL are:

1. Interface the LARS processed (reformatted) Landsat digital imagery with the JPL mosaicking software developed under VICAR/IBIS.
2. Prepare a digital mosaic of seven (7) Landsat scenes in four (4) spectral bands of the Oruro Department of Bolivia. The Landsat

imagery will be resampled to 50 meter by 50 meter pixels and map projected to the Albers equal area projection and; segment the final mosaic in 100 Kilometer (km) by 100 km quadrangles of 2000 lines by 2000 samples (columns) each. Corrections will be performed also to equalize side-lap brightness differences between scenes due to atmospheric haze.

3. Prepare one (1) color composite negative and proof contact print of bands 4, 5, and 7 for each 100 km x 100 km quadrangle.
4. Prepare a final report containing all relevant computer reports for the procedures used in compiling the mosaic.

The period of performance of these tasks is six months from the start of the work.

Purdue/LARS will provide at the start of work:

1. The seven (7) Landsat computer compatible tapes (CCT's) to be used for the mosaic.
2. Approximately twenty-five (25) ground control points (GCP's) identified in each frame selected for the mosaic task.

The status of this phase of the project is described in a latter section of this report entitled "Creation of the Oruro Department Landsat Digital Mosaic".

ASSESSMENT OF GEOCODING ALTERNATIVES

An exploratory assessment of geocoding alternatives was carried out by Dr. Roy Chung, professor of geography from Northern Iowa University under contract to Purdue University. Dr. Chung's study and recommendations regarding the advantages and disadvantages of vector (poligonal) and raster (grid cell) organization of spatial data are included in Appendix E of this report.

SELECTION OF INPUT CHANNELS (ELEMENTS) FOR THE BOLIVIAN GEOGRAPHIC INFORMATION SYSTEM

In order to select and prioritize the elements (channels) to be included in the Bolivian GIS, Prof. Roy Chung has documented a series of selection criteria (see Appendix F). Prof. Chung recommends that the following elements be included in the Bolivian GIS:

1. MSS 4
2. MSS 5
3. MSS 7
4. Departments and Provinces
5. Cantons
6. Elevation
7. Relief Amplitude or Local Relief
8. Slope and Aspects
9. Geology
10. Soils
11. Hydrology (drainage network)
12. Precipitation
13. Temperature
14. Land Cover and Land Use
15. Transportation
16. Population

Appendix F also contains a list of examples of the kinds of analysis and applications possible from a geographic information system such as the one being developed for Bolivia.

TECHNICAL DISCUSSIONS WITH BOLIVIAN PERSONNEL

During the period from July 24, 1980 to August 1, 1980, Terry L. Phillips and Luis A. Bartolucci worked in Bolivia with the technical personnel of the ERTS/GEOBOL Program. A summary of the accomplishments of this trip to Bolivia is included in Appendix G of this report.

CREATION OF THE LANDSAT DIGITAL MOSAIC

According to the project implementation plan (see Figure 1), the creation of the Landsat digital mosaic for the Oruro Department should have been initiated by JPL on October 1, 1980. However, it has not been possible to provide JPL with the Landsat CCT's and the required ground control points because of a number of unforeseen problems related to both the Landsat data quality and the lack of accuracy of the ground control points provided by the Programa ERTS/Bolivia.

The seven Landsat MSS scenes covering the Oruro Department (see Figure 7) were provided by the Programa ERTS/GEOBOL in Brazilian (INPE) CCT format. These tapes had to be reformatted to the NASA and LARSYS formats using the INPERTS and REFERTS software developed at LARS. Four of these scenes could not be successfully read or copied due to "read errors" as indicated in Table 3.

In order to correct the unreadable data records in the four Brazilian tapes, bad data lines were replaced by the nearest good data quality line as shown in Table 4.

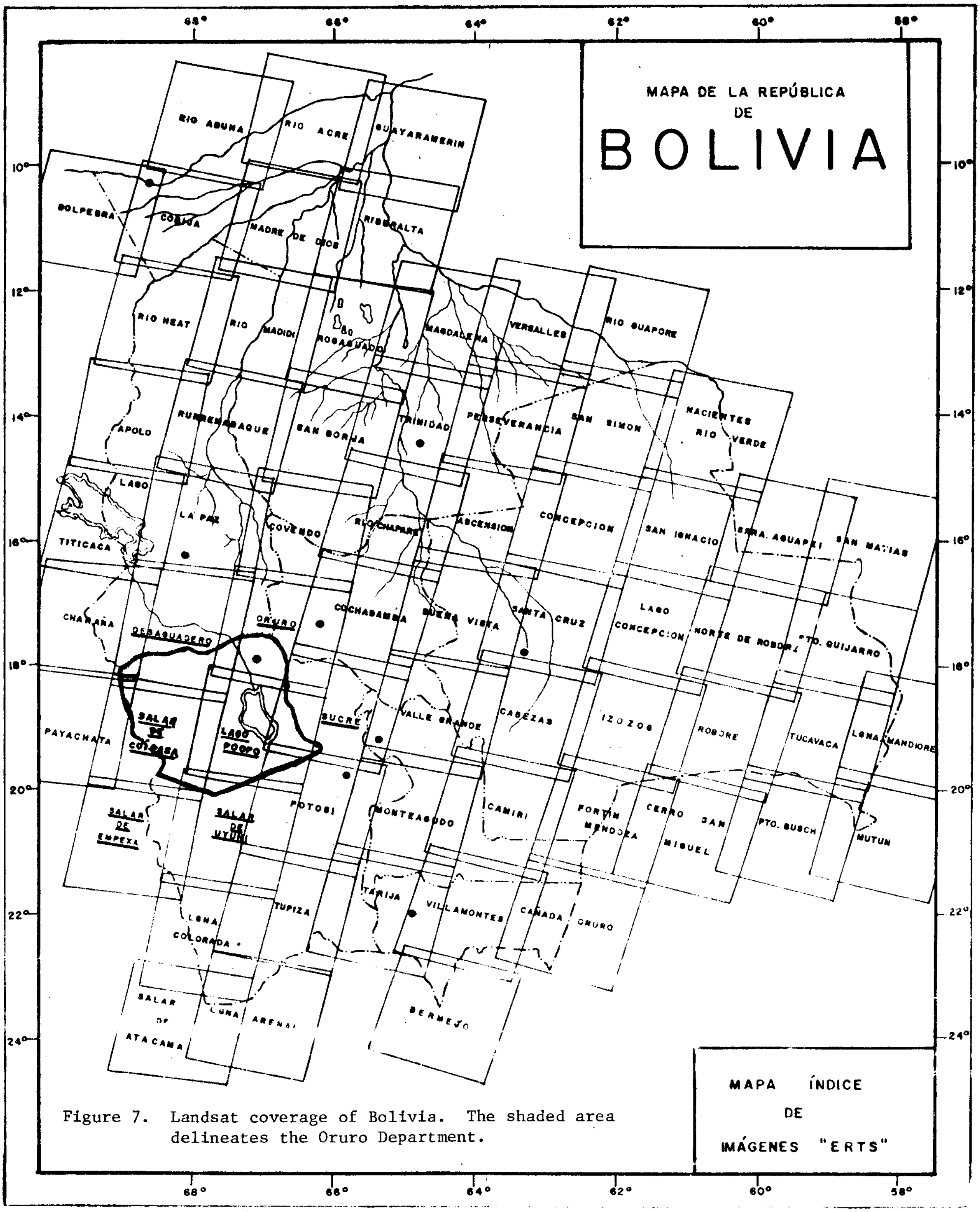

Figure 7. Landsat coverage of Bolivia. The shaded area delineates the Oruro Department.

Table 3. Read Errors in Brazilian (INPE) CCT's.

Frame	Scene ID	Problem
Oruro	76-157-13-13-40	Two read errors in strip 1
Desaguadero	77-251-13-27-14	Five read errors in strip 1
Coipasa	77-233-13-28-41	Two read errors in strip 2
Empexa	77-233-13-29-06	One read error in strip 6

Table 4. Replacement of Unreadable Data Records.

Name	Brazilian ID	Location of Unreadable Records	Data Line Replaced	Good Data Line Used For Replacement
Oruro	76-157-13-13-40	Strip 1 (Tape 1 of 2, File 1)	289 1451	288 1450
S. de Coipasa	77-233-13-28-41	Strip 1 (Tape 1 of 2, File 1)	4 5	3 3
S. de Empexa	77-233-13-29-6	Strip 6 (Tape 2 of 2, File 3)	14	13
Desaguadero	77-251-13-27-14	Strip 1 (Tape 1 of 2, File 1)	908 1041 1045 1049 1051	907 1040 1044 1048 1050

A Landsat scene in Brazilian (INPE) format is divided into 8 vertical strips. The Brazilian scenes with the replaced records were written to temporary tapes that were not saved.

The data in the Brazilian format were then converted to the NASA CCT X-format using the INPERTS program. The NASA format data were saved on tapes 5641-5654.

The data in NASA format were then converted to LARSYS format using the REFERTS program. The runs in LARSYS format were entered in the LARS runtable as indicated in Table 5.

Table 5. Identification and storage location of the seven Landsat CCT's covering the Oruro Department (see Figure 7 for location of the frames with respect to the Oruro Department.)

Name	Brazilian ID NASA ID LARS Run Number	NASA-Formatted Tapes	LARSYS-Format Tape/File
Oruro	76-157-13-13-40 5409-13134 76022500	5643, 5644	2836/3
Lago Poopo	76-157-13-14-05 5409-13140 76022400	5651, 5652	3769/1
Salar de Uyuni	77-232-13-23-26 2938-13284 77010300	5641, 5642	2868/1
S. de Coipasa	77-233-13-28-41 2939-13284 77010600	5649, 5650	3768/1
S. de Empexa	77-233-13-29-06 2939-13290 77010700	5653, 5654	3770/1
Desaguadero	77-251-13-27-14 2957-13271 77010500	5647, 5648	3767/1
Sucre	79-167-13-34-08 6601-13340 79005800	5645, 5646	3762/1

A gray scale VARIAN plotter image of each of the seven Landsat scenes and their corresponding data storage tape file information (LARS FORM 17D) are included in Appendix H of this report. Detail inspection of portions of these images revealed a severe data quality problem, which precluded the delivery of these data to JPL.

In order to assess the data quality of the entire data set, each one of the Landsat frames will have to be displayed in a COMTAL device. Since each frame will have to be subdivided into blocks of 512 lines by 512 columns and each one of the four spectral bands will have to be inspected, it is envisioned that it will take approximately two months to complete the data quality evaluation task.

The problem related to the accuracy of the control points required for the mozaicking and geometric rectification of the Landsat MSS data was encountered when the Landsat images were displayed and enlarged digitally to scales where each individual pixel was readily identifiable. Since the locations of the selected ground control points were marked on a black and white photographic print of the Landsat frames at a scale of 1:250,000, it was not possible to identify the location of the control points with the required accuracy of plus or minus 1 pixel (i.e., ± 80 meters). In addition to this problem, two of the Landsat 1:250,000 prints did not correspond to the Landsat digital data.

To attain the required accuracy of the ground control points, a new set of control points will have to be selected both in the digital data set and in the available topographic maps at a scale of 1:250,000. It is expected that this task will be accomplished concurrently with data quality evaluation task.

INPUT OF DATA BASE ELEMENTS (DIGITIZATION)

The process by which geo-referenced (spatial data contained in a standard map format) is converted to a format suitable for storage in a digital computer is known as digitization. In order to input the different data base elements (soils, land use, geologic maps, etc.) into the Bolivian digital geographic information system, one has to first of all convert these maps into digitized grid files.

A schematic configuration of the basic input process and data base updating subsystemsproposed for the Bolivian geographic information system is illustrated in Figure 8. These subsystems require specialized hardware and software components.

The hardware components of the digitizing capability presently available at LARS are: a TALOS Cybergraph table digitizer, a PDP 11/34 computer, a Tektronix 4054 graphics display, an IBM 3031 main frame computer, a COMTAL color digital display, a VARIAN dot-matrix printer/plotter, and interactive CRT terminals.

The software component of the digitizing subsystem is currently being updated and improved. It is expected that by the end of the next reporting period, the input process and data base updating subsystems will be fully operational and adequately documented.

Experience at LARS and other facilities has shown that the input (digitizing) process is the most time consuming step in developing a digital geographic information system.

SUMMARY OF ACCOMPLISHMENTS TO DATE

During this reporting period (August 1, 1980- October 31, 1980) the following tasks were accomplished:

- Completed the literature survey.
- Completed the System Design Draft.
- Completed evaluation of optimum map projection.

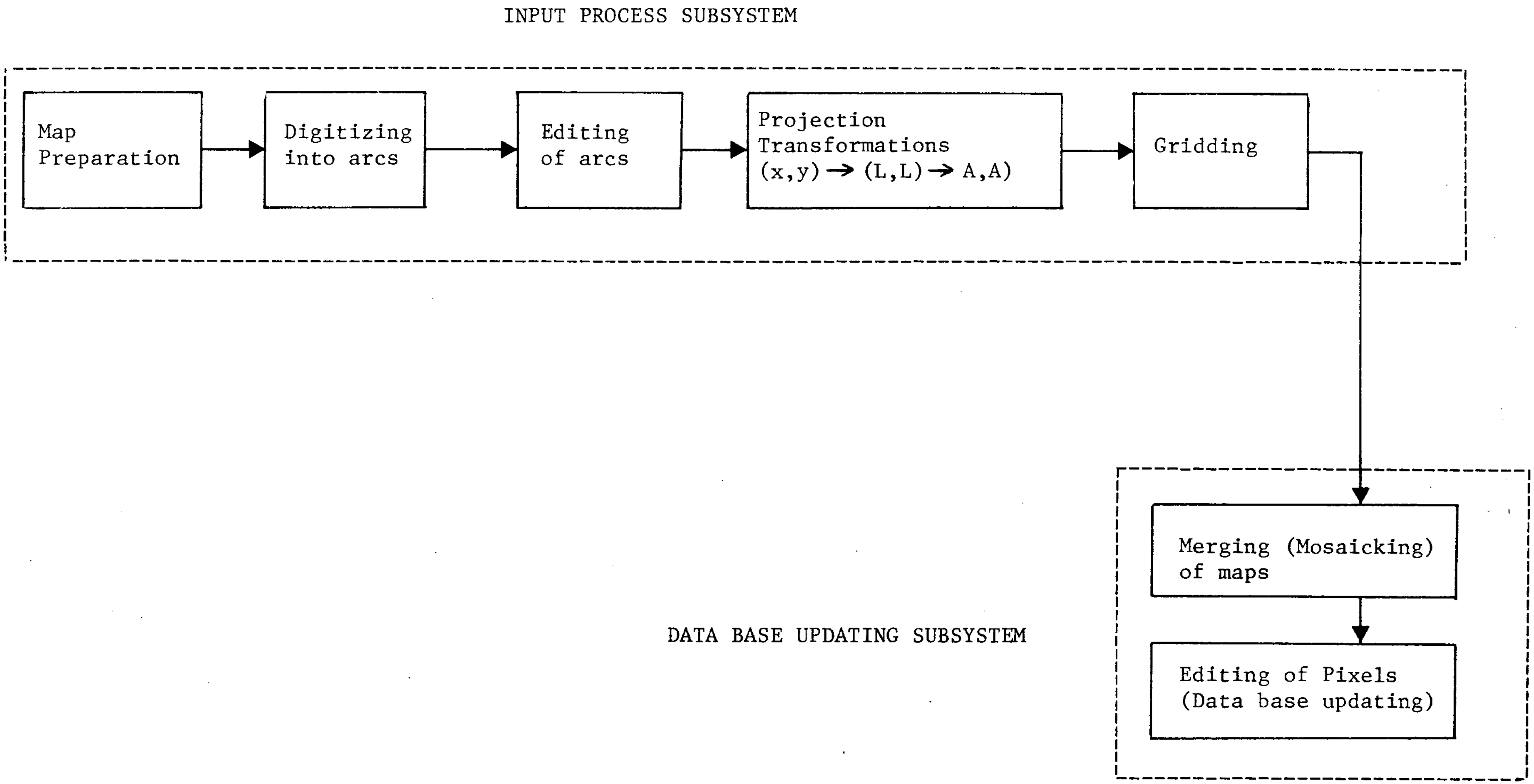

Figure 8. Input process and data base updating subsystem.

- Developed the Albers projection transformation.
- Specification of Landsat digital mosaic characteristics completed and initiated contractual procedures with the Jet Propulsion Laboratory.
- Assessment of geocoding alternatives completed and selected the grid (cellular) geocoding alternative for the Bolivian GIS.
- The input elements (or channels) for the Oruro Department GIS were selected.
- Extensive technical discussions with Bolivian project personnel took place in La Paz during the period July 24-August 1, 1980.
- Corrected "read errors" in the Brazilian (INPE) computer compatible tapes.
- Initiated data quality evaluation of the Landsat MSS images that will be used to create the Landsat mosaic.
- Started the selection of the ground control points in the Landsat MSS digital data and the corresponding geographic coordinates from the 1:250,000 topographic maps.
- Initiated the development and improvement of digitizing (data input process) software.

In summary, most phases of this project are being completed on schedule, i.e., according to the time table proposed in the project implementation plan shown in Figure 1. Only two project tasks have been delayed because of unpredicted problems. The creation of the Landsat digital mosaic has been delayed because of data quality and accuracy of ground control point problems, and the data input task has been delayed because improvements in the digitizing software are still being performed.

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APPENDIX B

Data Base Alternative Study

by

Terry L. Phillips

Table 1 shows data base alternative parameters for grid cell sizes of 50, 100, 200, 250, 400, 500, and 1,000 meters. Tables 2 and 3 show output device studies by data base alternatives. Table 4 shows this same information by scale as opposed to data base alternative.

In Table 1 the size of a cell in square meters and hectares is shown. Since a quadrant of 1 million cells with 16 elements per cell fits conveniently in an 800 bpi tape, the data can be stored on tape in 1,000 cell quadrants. The number of quadrants required to cover Bolivia is also shown in the table. Since the initial feasibility tests of this design will be conducted in the Oruro Department of Bolivia, the number of quadrants in the Oruro Department is also shown. The size of a quadrant side and the area of a quadrant is also shown in Table 1. For the various scales, the quadrant size on the map (in meters) is also shown. Finally, the number of cells in the Oruro Department has been estimated in millions of cells for each of the data base alternatives.

Tables 2 and 3 show an output device study by data base alternatives. Table 2 shows this study for a black-and-white output device having a dot pattern of 50, 75, 80, and 100 dots per centimeter. At the present time, the dot pattern of 80 dots per centimeter is the state-of-the-art and may be the only one which can be purchased. The table shows for a particular data base alternative and scale, the map size in centimeters and the square root of the number of dots which would be used to make a gray shade or a cell on the map.

The levels chosen for the Bolivian data base are the 50 meter cell size for the working (input) level, the 100 meter cell size for the local studies, the 500 meter cell size for (departmental) studies, and the 1,000 meter cell size for national studies.

Table 1. DATA BASE ALTERNATIVE STUDY

Data Base Alternative	50m	100m	200m	250m	400m	500m	1000m
Size of cell (in square meters)	2,500	10,000	20,000	62,500	160,000	250,000	1 x 10^6
Size of cell (in hectares)	.25	1	4	6.25	16	25	100
Quadrants in Bolivia	492	137	43	28	14	9	1
Quadrants in Oruro	33	12	4	4	1	2	1
Quadrants size (in kilometers)	50	100	200	250	400	500	1300 by 1500
Quadrant size (in square kilometers)	2,500	10,000	40,000	62,500	160,000	25,000	1.95 x 10^6
Quadrant size on map (in meters) 1/25,000	2	4	8	10	16	20	52 by 60
1/50,000	1	2	4	5	8	10	26 by 30
1/100,000	.5	1	2	2.5	4	5	13 by 15
1/250,000	.2	.4	.8	1	1.6	2	5.2 by 6
1/500,000	.1	.2	.4	.5	.8	1	2.6 by 3
1/1,000,000	.05	.1	.2	.25	.4	.5	1.3 by 1.5
Cells per Quadrant	1 x 10^6	1 x 10^6	1 x 10^6	1 x 10^6	1 x 10^6	1 x 10^6	1.95 x 10^6
Bytes per Quadrant	16 x 10^6	16 x 10^6	16 x 10^6	16 x 10^6	16 x 10^6	16 x 10^6	31.2 x 10^6
Cells in the Oruro Department (in millions of cells)	20	5	1.25	.8	.32	.20	.05

Table 2. BLACK AND WHITE OUTPUT DEVICE STUDY BY DATA BASE ALTERNATIVES

Data Base Alternative	Scale	Map Cell Size in cm	DOT PATTERN 50 Dots per cm	75 Dots per cm	80 Dots per cm	100 Dots per cm
50m	1/25,000	.2	10	15	16	20
50m	1/50,000	.1	5	--	8	10
50m	1/100,000	.05	--	--	4	5
100m	1/50,000	.2	10	15	16	20
100m	1/100,000	.1	5	--	8	10
100m	1/250,000	.04	--	--	--	4
200m	1/100,000	.2	10	15	16	20
200m	1/250,000	.08	4	6	--	8
200m	1/500,000	.04	--	--	--	4
250m	1/100,000	.25	--	--	20	25
250m	1/250,000	.1	5	--	8	10
250m	1/500,000	.05	--	--	4	5
400m	1/250,000	.16	8	12	--	16
400m	1/500,000	.08	4	6	--	8
400m	1/1,000,000	.04	--	--	--	4
500m	1/250,000	.2	10	15	16	20
500m	1/500,000	.1	5	--	8	10
500m	1/1,000,000	.05	--	--	4	5
1000m	1/500,000	.2	10	15	16	20
1000m	1/1,000,000	.1	5	--	8	10
1000m	1/2,000,000	.05	--	--	4	5

Table 3. COLOR OUTPUT DEVICE STUDY BY DATA BASE ALTERNATIVES

			DOT PATTERN		
Data Base Alternative	Scale	Map Cell Size in cm	50 Dots per cm	100 Dots per cm	200 Dots per cm
50m	1/25,000	.2	10	20	40
50m	1/50,000	.1	5	10	20
50m	1/100,000	.05	--	5	10
50m	1/250,000	.02	--	2	4
50m	1/500,000	.01	--	1	2
50m	1/1,000,000	.005	--	--	1
100m	1/50,000	.2	10	20	40
100m	1/100,000	.1	5	10	20
100m	1/250,000	.04	2	4	8
100m	1/500,000	.02.	1	2	4
100m	1/1,000,000	.01	--	--	1
100m	1/2,000,000	.005	--	--	1
200m	1/100,000	.2	10	20	40
200m	1/250,000	.08	4	8	16
200m	1/500,000	.04	2	4	8
200m	1/1,000,000	.02	1	2	4
200m	1/2,000,000	.01	--	1	2
200m	1/4,000,000	.005	--	--	1
250m	1/100,000	.25	--	25	50
250m	1/250,000	.1	5	10	20
250m	1/500,000	.05	--	5	10
250m	1/1,000,000	.025	--	--	5
250m	1/5,000,000	.005	--	--	1
400m	1/250,000	.16	8	16	32
400m	1/500,000	.08	4	8	16
400m	1/1,000,000	.04	2	4	8
400m	1/2,000,000	.02	1	2	4
400m	1/4,000,000	.01	--	1	2
400m	1/8,000,000	.005	--	--	1
500m	1/250,000	.2	10	20	40
500m	1/500,000	.1	5	10	20
500m	1/1,000,000	.05	--	5	10
500m	1/2,000,000	.025	--	--	5
500m	1/5,000,000	.01	--	1	2
500m	1/10,000,000	.005	--	--	1
1000m	1/500,000	.2	10	20	40
1000m	1/1,000,000	.1	5	10	20
1000m	1/2,000,000	.05	--	5	10
1000m	1/4,000,000	.025	--	--	5
1000m	1/5,000,000	.02	1	2	4
1000m	1/10,000,000	.01	--	1	2

Table 4. BLACK AND WHITE OUTPUT DEVICE STUDY BY SCALE

			DOT PATTERN			
Scale	Data Base Alternative	Map Cell Size in cm	50 Dots per cm	75 Dots per cm	80 Dots per cm	100 Dots per cm
1/25,000	50m	.2	10	15	16	20
1/50,000	50m	.1	5	--	8	10
	100m	.2	10	15	16	20
1/100,000	50m	.05	--	--	4	5
	100m	.1	5	--	8	10
	200m	.2	10	15	16	20
	250m	.25	--	--	20	25
1/250,000	100m	.04	--	--	--	4
	200m	.08	4	6	--	8
	250m	.1	5	--	8	10
	400m	.16	8	12	--	16
	500m	.2	10	15	16	20
1/500,000	200m	.04	--	--	--	4
	250m	.05	--	--	4	5
	400m	.08	4	6	--	8
	500m	.1	5	--	8	10
	1000m	.2	10	15	16	20
1/1,000,000	400m	.04	--	--	--	4
	500m	.05	--	--	4	5
	1000m	.1	5	--	8	10
1/2,000,000	1000m	.05	--	--	4	5

APPENDIX C

An Addressing Scheme for a Bolivian Natural Resources Data Base

Terry L. Phillips
November 4, 1980

The addressing scheme used in the Bolivian Natural Resources Data Base is based on the Albers conical equal-area projection with two standard parallels. This projection is thoroughly described by Deetz and Adams[1]. The rational for selecting this projection is the subject of the paper by Torrez[2].

The equations used to calculate the addresses are the subject of this paper.

The parameters chosen for calculating the projection are a = 6,378,160 meters for the Equatorial axis and b = 6,356,775 meters for the Polar axis[3]. The standard parallels are $\phi_1 = 12^{O}S$ and $\phi_2 = 20^{O}S$ and the standard meridian $\lambda_m = 64^{O}W$. These parallels and meridian are commonly used for mapping purposes in Bolivia.

The eccentricity "ε" of the spheroid is computed using the expression[3]:

$$\varepsilon^2 = \frac{a^2 - b^2}{a^2}$$

The radius of a sphere "c " having a surface equivalent to that of a spheriod is computed using the expression[1]:

$$c^2 = a^2(1 - \varepsilon^2)(1 + \frac{2}{3}\varepsilon^2 + \frac{3}{5}\varepsilon^4 + \frac{4}{7}\varepsilon^6)$$

The sine of the authalic latitude " β" is calculated using the expression[1]:

$$\mathrm{Sin}\beta = \mathrm{Sin}\phi\frac{(1 + \frac{2}{3}\varepsilon^2\mathrm{Sin}^2\phi + \frac{3}{5}\varepsilon^4\mathrm{Sin}^4\phi + \frac{4}{7}\varepsilon^6\mathrm{Sin}^6\phi)}{1 + \frac{2}{3}\varepsilon^2 + \frac{3}{5}\varepsilon^4 + \frac{4}{7}\varepsilon^6}$$

Next a special constant "n" is calculated[1]:

$$n = \frac{\dfrac{a^2\text{Cos}^2\phi_1}{1 - \varepsilon^2\text{Sin}^2\phi_1} - \dfrac{a^2\text{Cos}^2\phi_2}{1 - \varepsilon^2\text{Sin}^2\phi_2}}{2c^2(\text{Sin}\beta_2 - \text{Sin}\beta_1)}$$

Then a parameter "ρ" is calculated using the expression[1]:

$$\rho = \sqrt{\frac{2c^2}{n}(\text{Sin}\beta_1 - \text{Sin}\beta) + \frac{a^2\ \text{Cos}^2\phi_1}{n^2(1 - \varepsilon^2\text{Sin}^2\phi_1)}}$$

For $\theta = n(\lambda_m - \lambda)$ where "λ" is the longitude and "ρ" is computed at a latitude ϕ , the x, y coordinates are computed using the expression[1]:

$$x = \rho\text{Sin}\ \theta \quad \text{and} \quad y = \rho\text{Cos}\ \theta - \rho_0$$

for the center of the map at λ_m and $\frac{\phi_2 + \phi_1}{2}$.

The column number or column address of the input data base is:

$$X_I = \text{INTEGER}\left[\frac{x_0 + x}{50}\right]$$

and the line number or line address of the input data base is:

$$Y_I = \text{INTEGER}\left[\frac{x_0 + x}{50}\right]$$

where x_0 and y_0 are equal to a constant such that at $\lambda = 64.0^0$ and $\phi = 16.0^0$ $X_I = 13{,}400$ and $Y_I = 14{,}200$, and at $\lambda = 63.999999^0$ and $\phi = 16.000001^0$ $X_I = 13{,}401$ and $Y_I = 14{,}201$ and INTEGER is the largest Interger less than or equal to the value inside the expression.

If A_I is defined as X_I, Y_I or the address of the Input data base. Then A_L, A_R and A_N can be calculated using the equation:

$$A_J = (A_K + k - 1)/k$$

for J = I and K = L, R or N

J = L and K = R or N

and J = R and K = N

and $k = \frac{E_K}{E_J}$ and $E_I = 50$, $E_L = 100$, $E_R = 500$, and $E_N = 1{,}000$.

I, L, R and N are notations for the Input, Local, Regional and National data base levels.

The addressing relationships going the other way is

$$A_K = \text{Interger } (k * A_J - 1) \text{ for } 1 = 0 \text{ to } (k - 1)$$

A program entitled Bolivia Projection has been written for an Apple II Plus. A listing of this program is attached in Appendix A. For this program ρ_0 was calculated to be 22,248,393.4. x_0 was chosen to be 670,049.999 and y_0 was chosen to be 710,049.999. These parameters were chosen so that the address boundaries of one of the data points would be at the center of the map.

1. Deetz, C.H. and Adams, O.S.: "Elements of Map Projection", Special Publication 68, United States Department of Commerce, Coast and Geodetic Survey, 1944.

2. Torrez, Oscar, Rational for Selecting the Albers Conical Equal-Area Projection for the Bolivian Natural Resources Data Base: ERTS/GEOBOL LaPaz Bolivia, in Letter from Dr. Carlos E. Brockman, PST/D/1173/80, 14 November, 1980.

3. Richards, P. and Adler, R.K.: "Map Projections", American Elsevier Publishing Company, New York, 1972.

APPENDIX A

BOLIVIA PROJECTION

```
500  REM Calculate X and Y from latitude and longitude
505  REM Set Standard Parameters
510  GO SUB 950
515  REM Calculate constants
520  GO SUB 700

530  REM Input Latitude and Longitude
535  INPUT "Latitude = ?"; LT
536  IF LT = 0   GO TO 570
537  IF LT < 0   GO TO 575
540  INPUT "Longitude = ?"; LG
545  REM Calculate X and Y
550  GO SUB 600
555  PRINT "X = "; X; TAB(20); "Y = "; Y
560  PRINT "XX ="; XX; TAB(20); "YY ="; YY
565  GO TO 530
570  END

575  LT = 16.0
576  LG = 64.0000004
577  LG = LG - .0000001
578  GO SUB 600
579  PRINT "LG ="; LG; "XX ="; XX; "X ="; X
580  IF LG > 63.9999998 GO TO 577
585  LT = 15.9999997
586  LG = 64.0
587  LT = LT + .0000001
```

```
588  GO SUB 600

589  PRINT "LT ="; LT; "YY ="; YY; "Y ="; Y

590  IF LT < 16.0000001 GO TO 587

599  END
```

```
600  REM  Compute the SIN of the authalic latitude B3S

605  RC = RD * LT

610  T1 = Sin (RC)

615  T2 = T1 * T1

620  T4 = T2 * T2

625  T6 = T4 * T2


640  B3S = T1 * (1 + C1 * T2 + C2 * T4 + C3 * T6) /C9


650  REM Compute RO

655  RO = SQR (A1 - A2 * B3S + A3)

660  TH = RD * N * (MN - LG)

665  X = RO * SIN (TH)

670  Y = RO * COS(TH) - 22248393.4

675  XX = INT ((670049.999 + X) /50)

680  YY = INT ((710049.999 - Y) /50)


695  RETURN
```

```
700 REM Set Constants
705  AA = RE * RE  :REM A Squared
710  EE = (AA - RF * RF) /AA  :REM Eccentricity squared
715  C1 = 2 * EE /3
720  C2 = 3 * EE * EE /5
725  C3 = 4 * EE * EE * EE /7

735  C9 = 1 + C1 + C2 + C3
740  REM Calculate the radius squared of a sphere having a surface
    equivalent to that of a spheroid.
745  CC = AA * (1 - EE) * C9
750  PI = 4 * ATN (1.00)
755  RD = PI /180.00
760  RA = RD * P1  :REM Standard Parallel 1 in radians
765  RB = RD * P2  :REM standard Parallel 2 in radians
770  J1 = Cos (RA)
775  J2 = J1 * J1
780  K1 = Cos (RB)
785  K2 = K1 * K1
```

```
800  REM Compute the Sin of the authalic latitude for P1

805  R1 = SIN (RA)

810  R2 =R1 * R1

815  R4 = R2 * R2

820  R6 = R4 * R2

825  B1S = R1 * (1 + C1 * R2 +C2 * R4 + C3 * R6) /C9

830  REM Compute the Sin of the authalitic latitude for P2

835  S1 = SIN (RB)

840  S2 = S1 * S1

845  S4 = S2 * S2

850  S6 = S4 * S2

855  B2S = S1 * (1 + C1 * S2 + C2 * S4 + C3 * S6) /C9

860  REM Calculate the special constant N

865  N = AA * (J2/(1-EE * R2) - K2/(1 - EE * S2))/

                        (2.0 * CC * (B2S - B1S))

870  NN = N * N

875  REM Compute RO parameters A1, A2 and A3.

880  A2 = (2.0 * CC) /N

885  A1 = A2 * B1S

890  A3 = (AA * J2) / (NN * (1-EE * R2))

895  RETURN
```

```
950  REM Set Standard Parallels and Meridian

955  P1 = 12.00  :REM Standard Parallel A in degrees

960  P2 = 20.00  :REM Standard Parallel B in degrees

965  MN = 64.00  :REM Standard Meridian


975  RE = 6,378,160  :REM EQUATORIAL Axis

980  RF = 6,356,775  :REM Polar axis

990  RETURN
```

APPENDIX D

SERVICIO GEOLOGICO DE BOLIVIA

PROGRAMA DEL SATELITE TECNOLOGICO DE RECURSOS NATURALES

CALLE FEDERICO ZUAZO 1673
ESQ. REYES ORTIZ
TELEFONO 63474

CASILLA DE CORREO 2729
LA PAZ – BOLIVIA

PST/D/1173/80

La Paz, noviembre 14 de 1980

Señor
Dr. Luís A. Bartolucci Castedo
LARS PURDUE UNIVERSITY
1220 Potter Drive
West Lafayette IN., 47906
U.S.A.

Estimado Doctor:

En fecha 6 de los corrientes se recibó su cable solicitando justificación sobre uso de Proyección Albers al mismo tiempo los cálculos de la misma Proyección, también en fecha 7 de los corrientes solicitó la documentación actualizada de la división política del Departamento de Oruro.

Al respecto deseo indicarle lo siguiente:

1. Justificación sobre uso Proyección Albers.

   Esta primera consideración tiene un caracter histórico ya que hasta la fecha en el país no se ha realizado un cálculo especial ni un estudio apropiado para la utilización de una adecuada proyección de acuerdo a propósitos específicos.

   Es así que todas las proyecciones hasta hoy han sido solo copias dibujadas de mapas anteriores, sin considerar absolutamente la clase de información a compilarse sobre ellas.

   Se conoce por ejemplo que entre los primeros mapas levantados en la República está el mapa del Tcnl. Juán Ondarza, levantado del año -- 1842 al año 1859, durante el Gobierno de José María Linares y publicado en Nueva York . Este mapa toma como referencia longitudinal el Meridiano de París y no tiene dato de proyección.

   Otro mapa de gran tiraje el elaborado por la Comisión Mixta de Defensa Nacional en el año 1934, durante la Presidencia del Dr. Daniel Salamanca. Este documento tiene la Proyección Policónica Corregida.

   Hubieron muchos mapas más y a diferentes escalas, cuyos tirajes no fueron muy importantes. En la década pasada, se conoce la Carta Aeronaútica Mundial, cuya fracción para Bolivia al igual que para el mundo entero, tiene la Proyección Cónica Conforme de Lambert, cuyos paralelos comunes van mucho más allá de los límites especificados para el país.

   Ha tenido también un gran significado cartográfico-informativo el el mapa del Ing. Camacho Lara, cuya proyección es la Cónica conforme de Lambert.

De estos dos últimos mapas: Carta Aeronáutica Mundial y Mapa del Ing. Camacho Lara, proviene la compilación del primer Mapa Político editado en el país a escala 1:1.000.000 y con la Proyección Cónica Conforme de Lambert.

Existe también una tesis académica, en la Academia Nacional de Ciencias, que dá el posicionamiento para un Datum específico para Bolivia (San Lorenzo), con cuyo apoyo se dan los patrones de cálculo para la Proyección Cónica Conforme de Lambert, especial para los límites de Bolivia, que aún no ha sido utilizada para publicación alguna. (Tesis Académica: Ing. Oscar Wilde Fernández).

Por lo tanto en esta primera consideración podemos resumir que no se ha utilizado jamás un cálculo específico para la Proyección Conforme de Lambert para Bolivia, y que las existentes son simples calcos de las anteriores publicaciones nombradas.

La Proyección existente actualmente en Bolivia, a escalas pequeñas, Cónica Conforme de Lambert, como su nombre lo indica brinda conformidad de representación territorial, eliminando al máximo distorciones de forma, pero que ante ello implica deformación en la mesura de áreas.

Para poder contar con un sistema en el cual la representación cartográfica pueda ser medida aerealmente, se debe utilizar una Proyección adecuada, preferiblemente del tipo equiárea. Esta sería la Cónica Equiárea de Albers, la cual reduce al mínimo los errores inevitables en otros sistemas de proyección.

Albers distribuye igualmente el error de escala a lo largo y ancho de toda su representación de figura. Calcula una curva isométrica entre los paralelos seleccionados como comunes o standard, que permite conocer los mínimos errores y repartirlos igualmente.

Con el conocimiento de los factores de escala, que provienen de la curva isoperimétrica, para diferentes paralelos de latitud, es posible aplicar correcciones a la medición de distancias; recordando que el máximo de error en esta proyección puede provenir de la distorción del material donde se la plotea, más que del cálculo mismo.

El tiempo requerido para la construcción de esta proyección es un mínimo contra el tiempo empleado en cualquier otro sistema. Así por ejemplo se empleó para Bolivia en la construcción Albers a escala ---- 1:1.000.000, desde el cálculo, la computarización y el ploteo, solamente 45 días hábiles.

Albers es una de las pocas proyecciones que permite el buen empalme de hojas diferentes separadas, por su calidad de minimizar los errores de cálculo y ploteo.

El 7% del error que aproximadamente cuenta cualquier sistema de proyección, fué reducido por Albers al 1 1/4%. En este caso podemos nombrar a la Proyección Lambert que brinda un error del 5%. Esto fué calculado y comprobado por el U.S. Geological Survey; en la elaboración de su mapa mural a escala 1:2.500.000 de los EE.UU.

Para la inventariación y mapeo sistemático de Recursos Naturales es mucho más recomendable el uso de una Proyección Equiárea, que de una Proyección Conforme, debido a que prima la cuantificación aereal o mensura de superficie, asunto que brinda con mayor propiedad y precisión la Proyección Albers.

El rango de representación es mucho mayor en Albers que en cualquier otro sistema, debido al error de escala, ya que Albers permite representar desde 1:25.000 hasta 1:1.000.000 y menores aún. Para comparación podemos citar que el rango de la Proyección Albers Cónica Conforme, va aproximadamente desde escalas 1:500.000 y menores, no permitiendo de ninguna manera la representación a escalas grandes, para lo cual en Bolivia se recibe el apoyo del Sistema UTM.

El error de Acimuts en Albers, también es minimizado, asunto que brinda la oportunidad de utilizar datos Landsat mapeables por pixels los mismos que al computarizarse dependen de la minimización de defectos acimutales. Esta cualidad no tiene ningún sistema, por lo que para usos de registros cuantificables Landsat solo podría solventar el problema la Proyección Albers.

Los paralelos Standard Albers para Bolivia deberán ser aproximadamente aquellos que cubran el área entre 8°S y 24° S en latitud. Puede escogerse para ello los paralelos 12°S y 20°S con el apoyo del Meridiano Central de 64° de Long. W. Para cálculos se utilizarían las tablas del Esferoide Internacional.

2. Coordenadas Albers

El cálculo de coordenadas Albers (datos, proyección internacional A= 6378 388.000 mts). Adjunto lista completa.

3. Documentación Mapas Políticos del Departamento de Oruro

   1. Versión I.G.M.

   Este documento solamente contiene división política a nivel de Provincias que debe digitalizarse.

   2. Versión INE

   Documento completo que contiene hasta el nivel de Cantón, que también debe digitalizarse, junto a la lista de Cantones.

Considero de esta manera haberle dado curso a sus requerimientos.

Sin otro particular, aprovecho la oportunidad para expresarle mis consideraciones más distinguidas.

Dr. Carlos E. Brockmann
DIRECTOR PROGRAMA ERTS

ADJ.: Documentación
CB/adm.

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   AAAAAAAAA         LLL                  BBBBBBBBBBBB         EEEEEEEEE
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INTERNAL COMM

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FILE WILL BE DELETED AFTER PRINTING
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APPENDIX E

An Exploratory Assessment of the Geocoding Alternatives

by

Roy Chung

> "Serious investigations are needed to explore the relative utility of vector and raster organizations of spatial data and to identify the situations in which each of these approaches is most suitable." (Duane Marble and Donna Peuquet, 1976, p. 90).

The above quotation from Duane Marble and Donna Peuquet of the Geographic Information Systems Laboratory, State University of New York, Buffalo, dramatizes the awareness of the need for research about the geocoding alternatives; but a review of the literature disclosed no in-depth study explicitly devoted to this topic. The purpose of this phase of the report is to briefly explore the geocoding alternatives and arrive at an explicit recommendation for the Bolivian project.

Both grid data structure and polygonal data structure have been used in the past, but it appears that Geographical Information systems based on the grid have been more prevalent. The existence of two very recent reviews by long standing scholars in this field negates the need to survey this literature in depth in this report. I am referring to the excellent works of George Nagy and Sharad Wagle in Computing Surveys (1979), and of Kenneth Dueker in Geo-Processing (1979).

Among the factors often cited for the dominance of the grid structure in the past are:

1. The simplicity of grids as data structure.
   (Dutton and Nissen, 1978, p. 137)
2. In general, software development for almost any application is easier

for the cellular approach than for the alternative linked organization. (Nagy and Wagle, 1979, p. 160)

3. A regular grid has an implicit neighborhood function and finding a neighbor does not involve search nor extra computer time. (Peucker and Chrisman, 1975, p. 62)
4. One distinct advantage is that the regular geometry allows positional information to be implicit in the data stream. (Nichols, 1979, p. 3)
5. Other variables may be easily added.
6. The same set of grid cells are used for several variables.
7. Provides an easily understood system to evaluate suitability for any conceivable land use for which suitability criteria can be defined in terms of the grid cell data stored. (Buckner, 1977, p. 549)
8. Preferred over polygon where there is great complexity of pattern.
9. Simpler where you have to do your own programming.
10. Among the advantages of this structure is its direct correspondence to the format of raster-scanner input and matrix-plotter output.
11. Processing related to distance is also easily accommodated since the separation of any pair of points can be computed directly from their storage addresses. (10 & 11 from Nagy and Wagle, 1979, p. 160)

The major disadvantage of the cellular organization is its wasteful use of computer storage for spatially sparse data. (Nagy and Wagle, 1979, p. 161). Bryant and Zobrist (1976) call attention to "the problem of spatial resolution and cell size, and point out that the need for manual encoding of the input data files has made updating difficult and even prohibitively expensive and effectively limited the spatial resolution of grid cells to satisfy the need to achieve regional coverage' (p. 1A-2).

Other disadvantages brought up, such as errors in estimating perimeter, and shape, seem to be related to the issue of optimal cell size relative to level of resolution. No list of disadvantages would be complete without David Mark's (1979) views as expressed in "Phenomenon-based data-structuring and digital terrain modelling".. He concludes: "This paper reaches the undoubtedly controversial conclusion that regular square grids are not an appropriate data structure for DTM's (digital terrain modelling), since they do not correspond with the 'structure of the phenomenon' as it is viewed by any of the groups of terrain specialists" (pp. 34-35).

The point to note about Mark's views whether accepted or not, is that the rationale is not based on the data capture format, nor is it based on the internal storage or output of the machine, but is based on some conceptual perception of the properties of the phenomenon to be modelled. This phenomenon-based view is also shared by Francois Bouille (1977).

This section will now review some of the advantages and disadvantages of the polygonal data structure as reflected in the literature. The following taken from Dutton and Nissen (1978) will serve as an introduction:

> The other major approach in handling cartographic data involves vector data structures. Vector storage relates to keeping data as line descriptions, where natural or cultural features such as coastlines or state boundaries from maps describing the location of points where each line changes direction. Linear features are thus described as lists of coordinates, which break curved lines into a series of straight segments.
>
> ...Closed figures, such as counties or islands, are described by following their boundaries to make a circuit, ending with the same point where digitizing began. Algorithms exist which can recognize those closed figures (which are generically termed polygons). Given such a polygon, algorithms can be applied to calculate its area, its center of gravity, and perimater, and to determine whether a given location is inside it or outside. (p. 137, 140).

Some examples of advantages of the polygon data structure are offered below:

1. Gridded data cannot be measured with the precision that polygon recording offers; and point and line data lose their precise relationship with other data within the same grid cell, because their presence, rather than their location within the cell, is recorded. (Calkins and Tomlinson, 1977, p. 175)
2. Polygon format is widely used to describe administrative zones, such as counties or census tracts. In fact, when such zones vary greatly in size, as do census tracts, polygonal descriptions are the most sensible approach. (Dutton and Nisen, 1978, p. 140)
3. There is a perception that polygon files are cheaper to implement. Margaret Powers (1975) writes: "In the future, the advantage in time and money may lie with polygon systems. ...Since human labor has become more expensive and computer time has become cheaper since this study was done in 1968, the polygon system would have an even stronger advantage today." (p. 35)
4. Can change scale and do shape analysis.
5. Uses less storage once identified, compared to thousands of cells for each one polygon area.
6. Not restricted to 0-225 values for polygonal data structure.

Since many of the advantages of one system are disadvantages of the other, it will suffice to cite only a few major disadvantages of the polygonal data structure:

> We might mention here that we believe overlay modelling of multiple parameters is best attempted with the use of grid-based modelling techniques. Our experience has been that polygon overlay modelling involving line intersection analysis is costly to process, can result

> in misleading information and also produces graphic results which are confusing to interpret for planning purposes and particularly for presentation. Also, automated attempts to "clear" up this type of graphics are often misleading in their final results. (Dangermond, 1978, p. 27).

This view is also shared by Bryant and Zobrist (1978). They write:

> It is worth noting here that many of these operations are difficult and time consuming if the working data base is in polygon or graphical format (i.e., lines are specified by their end points and a district is given by a sequence of line segments). In particular, the operation called polygon overlay which solves primitive problems four and five is extremely difficult to perform on large files in graphical format. (p. 7).

Finally, Dueker (1979) calls attention to the fact that:

> Polygon encoding (one logical record per polygon) of cartographic data necessitates that 'every line is digitized twice--once for the polygon on the left of the line, and once for the polygon on the right. Even the most meticulous of map preparations cannot prevent X and Y coordinates from being generated from the same point.' (Dangermond, 1978, appendix 1.) Users of polygon encoding have found it necessary to develop procedures and programs to reconcile coordinates for a common line across separately digitized polygons to remove "slivers and gaps." (p. 109).

Some Confounding Issues in Data Structure Assessment.

4.1 The issue of terminology.

Ken Dueker (1979) writes: "The terminology used in geographic information systems has been confusing. Each system design seemingly invents its own terms for cartographic data" (p. 108). If one considers the terms 'grid' and 'polygon' as category names in a systematic classification, and attempts to work backwards and identify the differentiating characteristics or the criteria by which the differentiation was made, it would be clear that the format of the map or media from which the data was being captured was not the differentiating characteristic. A polygon source map could be data captured by either polygon or grid methods. This leaves the method of data capture and the method of data storage in the computer system as candidates for the differentiating characteristic.

Now consider the three principal geocoding architectures proposed by Bryant and Zobrist (1976, p. 1A-2). They proposed Grid Cell, Polygon and Image Raster. The problem is that both 'grid cell' and 'image raster' end up being cellular in storage! Reordering their scheme slightly comes up with:

$$\text{Cellular} \begin{cases} \text{(grid cell)} \\ \text{(image raster)} \end{cases}$$

Polygonal

The differences between what they call 'grid cell' and 'image raster' now seem to be differences in 'scale of unit storage cell' and differences in method of data capture from the source map or media. The pattern structure of data storage seems to be the primary differentiating characteristic, which results in a twofold categorization; and the scale or fineness of the cells seems to be the secondary differentiating characteristic. The issue is still not entirely resolved however, because it seems that method of data capture according to their discussion is also an equal candidate for secondary differentiating characteristic. Grid cell was captured by manual operation and image raster was captured by ultra-fine image processing technology.

Finally, the Harvard based scholars, Dutton and Nissen (1978), in an apparently independent attempt to enlighten the public write:

> The use of gridded data has become prevalent for several reasons. One is the simplicity of grids as data structures. ...Another reason is that data can be automatically captured by image scanning in a grid or raster format (the distinction between a grid and a raster is small, often only based on the size or number of cells used; also, "raster" is frequently applied to data as captured or as displayed, while "grid" is applied to data as stored or manipulated).

This dazzling display of verbal obfuscation only serves to underscore the confounding nature of data structure terminology in geographical information systems. Without a clearly defined differentiating characteristic, the nominal labels for the categories 'grid' and 'raster' do not point to mutually exclusive categories.

4.2 The lack of a conceptual basis for evaluation of the effectiveness of a geographical information system.

The literature reviewed is replete with examples of evaluation of data structure based on the source of data capture, the method of data capture, the kind of data storage, and some mention of output. Francois Bouille (1977) and David Mark's (1979) attempt to include the conceptual perception of the properties of the phenomenon being investigated seems to be a rarity. The traditional focus on point, line, and area properties of phenomena really refer only to pattern site traits of the phenomena and are theoretically sterile points of departure for understanding the phenomena set as a spatial interacting system.

If we view the spatial information system as a whole system, it becomes clear that the spatial explanatory models into which the output will or should flow, has been neglected as an important determinant of the data base organizational structure. This is a surprising discovery, particularly since one of the classic prototype of spatial information systems developed by geographers at the Royal University of Lund, Sweden, explicitly considered the spatial analytical models into which the information would ultimately flow as an important consideration in data structure selection. I am referring to such works as Nordbeck (1962) "Location of Areal Data for Computer Processing", Nordbeck and Rystedt (1969) "Computer Cartography Range Map", and Nordbeck and Rystedt (1972) Computer Cartography: The Mapping System Normap, Location Models.

Sweden is "probably the world's most registered population" (Nordbeck, 1972, p. 14). Nordbeck reports that a large number of offical registers exist, also the individual citizen has the responsibility for making sure that these registers contain correct information about himself. Also the parish books or the registration lists can be used to give detailed information about the number of persons resident at a particular property. The location of each property is described by a detailed coordinate system. With this kind of ideal data source, the Swedish geographers have built a spatial information system based on a grid data structure format.

Examples of spatial modelling based on the information flow from this system are:

1. Calculating the transporation costs for alternative locations of one manufacturing plant.

2. Finding the optimal locations and capacities for multiple units simultaneously
3. Locating multiple service facilities
4. The location of information processing and contact dependent activities.

These set of models come under the general name of Location-allocation problems in the contemporary American Regional Science literature. The regular ordered cellular data structure organization lends itself admirably to this kind of spatial modelling. The individual cell units are almost point-specific and distance and directional measures can be readily calculated from the cellular network.

Ken Dueker (1979) has perceptively identified "the effects on planning decisions of geographic information systems" (p. 124), as a measure of the viability or effectiveness of a system. Did the system make a difference? Was it used? He cited the Zulia study by Jack Dangermond as an example of a system that was used in the planning process and did make a difference. From this viewpoint the Swedish system has to be ideal. It is supported by an ongoing system of population registers, coded by x, y coordinates at the individual property level, and hierarchically merged into a national grid system. Furthermore Swedish planners rely heavily on the system and its models to find answers to planning questions raised.

It becomes most apparent that a data structure decision ought to be a function of the nature of the phenomena being studied, the data source, data capture technology, storage, and the output and intended analytical models into which it will flow.

5. An Exploratory Assessment

Although the perception of the issue of grid versus polygon as a "controversy" still rages strong in the current literature, my concluding assessment is that the state-of-the-arts technology has caught up or overtaken the grid versus polygon geocoding structure controversy. Moreover this dichotomy is vanishing not only from a technology improvement path, but also from a programming algorithmic development pathway.

5.1 Technology Improvement

The main area is improvement in the automation of the data capture process from source maps or other media. The image processing technology described by Bryant and Zobrist (1976) is an example of this:

> Digital image processing techniques can be applied to interface existing geocoded data sets and information management systems with thematic maps and remotely sensed imagery. The basic premise is that geocoded data sets can be referenced to a raster scan that is equivalent to an ultra-fine mesh grid cell data set, and that images taken of thematic maps or remote sensing platforms can be converted to a raster scan.... Such a system should permit the rapid incorporation of data sets, rapid comparison of data sets, and adaptation to variable scales by resampling the raster scans. (p. 1A-3)

5.2 Algorithmic Improvements in Software Developments

Programs for conversion from cellular to polygon data files and from polygon to cellular files are already operational. One may select the mode of data capture within the bounds of cost constraint and convert internally to a particular file structure depending on the analysis to which it may be subjected. Lowe (1978), Teicholz (1978) and Nichols (1979) report on operational conversion systems. Teicholz (1978) writes that "true polygon overlay with complete identification of intersections exists with ODYSSEY" (p. 7).

Nagy and Wagle (1979) report on a versatile new algorithm for conversion of polygonal maps to cellular maps; while the mathematical geographer Michael Goodchild reports on improved algorithms for the estimation of perimeter and shape from grid data. (Goodchild and Moy, 1976).

5.3 Improvements in Organizational System Design

There are continuing examples of successful operational systems where data capture is in a manual mode for both grid cell data structure and also for polygon data structure. Ben Buckner (1977) in an unusually clear article describes the actual use of the grid cell as a manual data capture process from maps and photos. Tillman and his associates (1977, 1980) report on a manual data capture system in grid cell format and its successful implementation on a micro-computer system.

These improvements do not nullify the need to make a decision as to the primary mode of data capture for a particular geographic information system. These decisions have to be made in an integrated optimization framework, involving constraints of cost, data source, hardware, software, organization, analytical models, and the decision institutions of the recipients of the geographical information system.

6. A Recommendation and Rationale

6.1 Recommendation

The most promising approach to the implementation of a general purpose Geographic Information System in Bolivia is to adopt the cellular data structure as the primary form of data storage.

6.2 Rationale

Currently, improvements in data capture technology and software algorithms have blurred some of the competitive issues between the cellular data structure and the polygonal data structure. However, issues concerning nature of the phenomena being studied, and the uses to which the outflow from the geographical information will be applied, still loom large in the selection of a data structure mode. It is appropriate to examine the rationale from, a) the phenomenon based criteria, and b) the applications of the output flow criteria.

6.21 Phenomenon-based Criteria

6.211 The primary data source for the land cover data will be from remotely sensed satellite data which is stored in a cellular raster scan format. This provides what may be viewed as a kind of base data source against which other data may be compared or displayed. It seems logical to merge the format of the incoming data from other sources to the primary base data source, than vice versa.

6.212 Enough emphasis has not been given to the sheer volume of data involved in geographical information systems at the national and regional scale. The implicit storage of the regular ordered grid data structure becomes a decisive factor in this context.

6.213 Mark (1979) has reached negative conclusions about the grid structure because as he sees it, it does not correspond with "the structure of the phenomenon" as it is viewed by the terrain specialists. (pp. 34-35) Since he was referring to digital terrain modelling, and since terrain attributes are a major component of the data elements in this proposed geographical information system, his views need to be taken into account. The issue of whether the grid cell structure can capture linear or other point sequential type data patterns really resolve down to a question of size of the unit cell of the gridded network. At the level of resolution of the cellular structure of the proposed model for the Bolivian system, it is my conviction that the spatial pattern organization of terrain data will be adequately displayed and will not be in competition with the gridded structure of the map pixels.

A decisive argument however is the explicit spatial nature of most terrain analytical models. As Peucker and Chrisman (1975) have effectively pointed out: "Most numerical computations on surfaces require some type of NEIGHBORHOOD FUNCTION, either to compute some surface behavior such as slope, or local variation of relief.." Note that slope, local variation of relief and aspects are prominent data elements in our proposed model. Peucker and Chrisman then continue: "A regualr grid on the other hand has an IMPLICIT NEIGHBORHOOD FUNCTION and finding a neighbor does not involve search nor extra computer time.

My conclusion is that precisely for reasons based on the phenomenon-structure point of view, the cellular data structure is most appropriate for the Bolivian model.

The state-of-the-arts of data management and software algorithms makes it possible to store political divisions as grid formats for merging with cellular Landsat data, and also to retain polygon files of these political divisions for pointer-structure linkages with other forms of census type data stored in non-cellular format.

6.31 Criteria Based on Applications and Models of the Output Flow.

6.311 There are certain "primitives" about spatial information. These are, a) distance, b) direction and one might add an explicit location in space.

Most spatial modelling involves calculation of distance, direction and interaction over distances in particular directions. For these purposes the cellular grid structure is most appropriate if the issue of size of grid is nullified by the level of resolution of the selected pixel size. Moreover some of these measurements are implicit because of the cellular ordered grid structure. Contiguity relationships, which are important in spatial diffusion modelling can best be derived from a cellular structure.

6.311 Finally, there is the fact of working models based on the grid-structure. The Swedish example previously discussed is an ideal example of how sophisticated spatial data analysis can be optimally integrated with a grid structure based geographical information system. I would also like to call attention to the current system being implemented in Japan and reported on by Hosoi Shosuke (1976). His model resembles that proposed for Bolivia. It is what I would call a hierarchical nested grid system in which each lower level is an explicit ordered subset of the higher level. More significant is his nominal numbering of the system, where the nested hierarchy is retained in the nominal number assigned to the lowest level. The cellular grid for the Bolivian model has an IMPLICIT nested hierarchical structure.

In conclusion, the grid based data structure does not prevent conversion to other structures for specific types of analysis; but the inherent ordered geometry of the cellular network makes it superior for spatial data modelling at the scale of regional analysis planned for Bolivia.

APPENDIX F

Selection of the Input Channels for the Bolivian G.I.S.

by

Prof. Roy Chung

1. Criteria for selection

It would be operationally most useful to spell out the criteria for selection.

1.1 The range of possible alternatives

Examine the range of development literature and list candidates for inclusion as channels.

Examine geographical information systems, operational and experimental, to see which ones have been implemented and used effectively and successfully.

1.2 Range of possible applications

Consider the possible uses which might be made of this data base. While this is not a general data base, it is also not an application specific data base. However, some notion of the range and scale of possible applications need to be considered.

It is important that possible uses be considered from the viewpoint of how LARS scientists see it, and how the Bolivians see it.

The recommended channels should include a recommended list and 'alternatives'. This should be revised after a Bolivian committee (working with LARS representatives) has come up with a priority rating of probable and needed applications. This institutional participation of the recipient of the information system is vital.

1.3 The availability of data

A common denominator is that this data will be spatially referenced and ultimately available in some thematic map form. This includes permanent maps, temporary maps (CRT displays), and digitally stored maps on the computer.

The cost factor will vary considerably depending on whether the data need to be processed and interpreted prior to transformation into map form as in MSS data source, or whether field surveys or census records are the main data source.

1.4 The technical capability of the recipients

On this factor the Bolivians rate very high both in terms of ability to handle MSS data sources and aerial photo data sources.

1.5 The algorithmic fertility of the data

The notions of explicit and implicit data items are standard in data base terminology. For example a soil type may be explicitly included, and its x, y coordinates implicitly available by its position in an ordered regular cellular array.

David Mark (1979) defined algorithmic relations as "ones which are neither implicitly nor explicitly indicated, but which nevertheless may be 'discovered' through an analysis of some or all of the data" (p. 28). Jack Dangermond (1978, p. 11) referred to "derived variables." Elevation is a good example of a terrain data item which is algorithmically fertile in the sense that many significant morphometric terrain relationships, such as relief amplitude and slope, may be derived from it. Many more examples of these derived attributes may be found in Evans (1972) and Verstappen (1977).

When several items of the same class exist, some parsimony may be achieved by considering the algorithmic fertility of the items.

1.6 Discrete versus continuous data

Often data are available but not for all geographical areas. If the data are continuous (for example, temperature), or can be treated as a continuous variable (like income), then measurements of these attributes can be approximated by some function such as:

$$z' = f(x,y)$$

where z' is the predicted measurement value

and x and y are the coordinates.

This model is well known as trend surface analysis, and used in many disciplines which deal with spatially referenced data, such as geology, geophysics, and geography.

As an example, the network of temperature collecting stations may be sparse in Bolivia. A second or third degree trend surface may be a close enough approximation to allow allocation of specific values to all Bolivia. The technique may be particularly useful for interval scaled phenomena for which data are only available at limited points.

1.7 The measurement scale at which the data is available

I am referring here to Steven's psychological scales of nominal, ordinal, interval and ratio. Nominal scale is basic to all information. At this scale you can identify it or differentiate it or note its presence or absence and record it (1,0). When a phenomenon is named or identified, it is at least measured at a psychological nominal scale.

Ordinal scale allows not only identification, but explicitly conveys some notion of ranking. Interval and ratio scales are what usually go under the "label quantitative". Interval scales have an arbitrary or assumed zero, example degrees fahrenheit; while ratio scales have a true zero and can therefore be expressed as a ratio.

Often we think of something as not measureable and so it is not considered for inclusion in a data base. However all traits are measureable at the nominal scale if they are distinguishable at all. Coding this so called qualitative attributes in (1, 0) notation, can allow important cross tabulations and even analyses based on non-parametric similarity matrices. Ordinal scale transformations are present in many data bases, example high elevation, moderate elevation, and low elevations. These also permit cross tabulations and numerical spatial boolean operations.

Psychological scaling considerations will minimize the chance of neglecting significant variables which may be excluded from the data base because they are considered to be "qualitative" and therefore not measureable nor recordable in a spatially referenced format. The fact is that most land use maps from MSS sources are at the nominal scale recorded as categorical types without any explicit ordinal implications.

1.8 Evaluating the data from the perspective of functional classifications

Classifications are not mere mechanical categories, but quite often the ordered classes have functional meaning which provide penetrative insight into the 'zusammenhangen' of the system being investigated. Calkins and Tomlinson (1977) provide one such categorization into demand data and supply data, which is extremely useful.

The human socio-economic system may be conceptualized as consisting of demand or consumption factors on the one hand, and supply factors which provide for those demands. A data base of information on soils, forest, terrain types, crops, etc., is really an information system about the supply or resource factors in the socio-economic system. Such an information system is inherently one-sided or unbalanced, if the supply is not related to the need or consumption or demand side of the system.

Data on demographics, labor force, income, transportation, and the quality of life (Morris, 1980) provide the basis for synthesis, interaction, and evaluation of the merits of the data base as a system. The equation needs not only supply data (land and resources) but also demand data (factors affecting human needs). A critical issue is thus, which of the myriad demand type data should be included, if any.

1.9 The hardware constraints.

An example is the bit limitiation on the number of categories which may be included for a data item.

1.10 The analytical models and capabilities to be built into the system.

Mere data collecting and fancy cartographic outputs do not constitute an information for development purposes. The analytical models into which the information would be fed, for ultimate transmission to the decision and policy makers, should be a part of the conceptualization of the spatial information system. This is particularly important in a system which is to be part of a technology transfer project to a developing country.

2. Input Channels or Data Base Variables

1. MSS 4
2. MSS 5
3. MSS 7
4. Departments and Provinces
5. Cantons
6. Elevation
7. Relief Amplitude or Local Relief
8. Slope and Aspects
9. Geology
10. Soils
11. Hydrology (drainage network)
12. Precipitation
13. Temperature
14. Land Cover and Land Use
15. Transportation
16. Population

3. Discussion of the Data Base Variables

3.1 Terminology

The terms "channels" or "layers" are more appropriate with respect to the conceptualization of the arrangement of the data inside the computer. Variables or data elements are more appropriate to the way the data analyst perceives his data. It is conventional to view the array of data as a data matrix. One row vector would be a set of attribute values about a single object, entity or case; while a column vector would show the variations in values of a single attribute over a set of objects, cases or entities.

Many canned statistical software packages use "Cases" for their objects, for example SPSS and SAS. David Sinton (1976) in his documentation for the Harvard software IMGRID points out that for geographical data bases, the ENTITY would be a location, and a set of observations about this entity or location (such as soils, slope, vegetation) would be the data elements (or variables as used above).

3.2 The implementation of these variables into the data base, and their further differentation into Levels I, II, and III, is greatly enhanced by the excellent work already done by the Bolivians. Carlos Brockmann's studies of land use classification (Brockmann and Brooner, 1975; Brockmann, 1978), and the integrated surveys of natural resources by Valenzuela R. and associates (Valenzuela R., Ballon A., Valenzuela A., and Michel, 1980), are examples of the high caliber of work.

Brockmann's land cover and land use map, 1978, is divided into eight Level I elements:

3.21 Range and/or scrublands

3.22 Forest

3.23 Croplands

3.24 Wet and/or Floodedlands

3.25 Waterbodies

3.26 Barrenlands

3.27 Permanent Snow and Ice

3.28 Cultural Patterns

Elevation categories of Highland range, Intermediate altitude range, and Lowland range, provide an ordinal scale differentiating characteristics to subdivide the Level I elements into Level II subelements. Perhaps the only modification I would suggest at this stage, might be the elevation of mining and other primary point extractive industries to a Level I category.

3.3 Climatic variables

Precipitation and temperature would provide the basis for Koppen type classification, or modified versions like Trewartha's. However, if evapotranspiration can be included from possible net radiation measurements, the Thornthwaite's climatic classification can be done for Bolivia. This classification is more useful for agricultural and soil applications.

3.4 Morphometric variables

Elevation, slope, aspects and local relief are basic ingredients to many algorithmically derivable concepts in geomorphology.

3.5 MSS variables

The inclusion of MSS 4, 5, and 7 permits the use of orthophotomaps as the base map for display of thematic maps of the other variables.

3.6 Political boundaries

Cantons and Provinces permit pointer-structure linkages to a wide range of socio-economic data available from census and reports by those units. Also, since these are often political decision units, it enables the analyst to relate land resource base regions to political decision regions.

3.7 Population and Transportation

The "resource" concept has no meaning without people. The ability to objectively relate the land resource base to population distribution, and to evaluate the optimality of the spatial linkages between resources and population, are some of the benefits of including population and transportation in the data base.

4. Selected examples of kinds of analysis and applications possible from this data base.

4.1 Geomorphological analysis

4.11 Terrain site analysis for location problems

4.12 Landform classification and Mapping. For example the Hammond Landform Map of the United States in the National Atlas of the United States is based entirely on crosstabulation categories of slope and local relief.

4.2 Drainage network analysis.

4.21 Watershed delineation

4.22 Irrigation and flooding studies

4.23 Regional river-basin based development planning

4.3 Climatic classification and mapping

4.4 Potential Land Capability studies

4.5 Zoning

4.6 Transportation studies

- 4.61 Highway location
- 4.62 Accessibilities studies

4.7 Demographic studies

- 4.71 Population potential
- 4.72 Population distribution
- 4.73 Population density
- 4.74 Man/land ratios
- 4.75 Market potential studies
- 4.76 Migration studies
- 4.77 Location-allocation studies
  - 4.771 Location of public facilities
  - 4.772 Park and recreational location relative to people
- 4.78 Regional population forecasts

4.8 Integrated numerical regionalization studies as the basis for planning.

4.9 Analyzing and modeling change in land use, population and settlements.

APPENDIX G

TRIP REPORT

Bolivian Geographic Information System

La Paz, Bolivia, July 24-August 1, 1980

Terry Phillips and Luis Bartolucci

INTRODUCTION

Terry Phillips and Luis Bartolucci arrived in La Paz, Bolivia on July 24 at 11:30 am and started working with the Bolivian remote sensing program (ERTS/GEOBOL) staff immediately upon arrival. The work continued until the afternoon of Friday, August 1.

Dr. Carlos E. Brockmann, Director of ERTS/GEOBOL and the technical staff assigned to this project worked jointly with us on various aspects of the project. The technical personnel involved were:

Dr. Carlos E. Brockmann, Director

Ing. Carlos Valenzuela, Agronomist (Soils and Land Use)

Ing. Percy Grundy, Civil Engineer (LARSYS Programming)

Ing. Rene Valenzuela, Geologist

Ing. Leonardo Prudencio, Civil Engineer (LARSYS Programming)

Ing. Oscar Tórrez, Industrial Engineer (Cartographer)

Ing. Juan Carlos Quiroga, Agronomist (Crop prediction models)

Lic. Rosario S. de Obrego, Sociologist (Socio-economic models)

We were highly impressed with the degree of technical competency and enthusiasm shown by the ERTS/GEOBOL staff. Essentially, the work performed during our stay in Bolivia conisted primarily of meetings in which we presented the system design draft that had been prepared prior to our departure to Bolivia.

These presentations generated extended discussions which will provide useful guidance for the development of the Geographic Information System of Oruro.

INFORMATION SYSTEM DESIGN DRAFT

The Information System Design Draft prepared by Terry Phillips describes the structure of a system proposed for Bolivia. It is essentially a four level 16 element grid structure. The Bolivian scientists were in complete agreement with the prepared system structure, that is:

1. To have four separate but interrelated data bases for different levels of information detail:
   - 50 m X 50 m grid cells for data input,
   - 100 m X 100 m grid cells for output products at a scale of 1:50,000,
   - 500 m X 500 m grid cells for output products at a scale of 1:250,000,
   - 1000 m X 1000 m grid cells for output products at a scale of 1:1,000,000,
2. The data bases will be subdivided into quadrants of 1000 X 1000 cells.
3. The input grid cell size (50 m X 50 m) corresponds to an input map at 1:25,000 with a 0.2 cm minimum mapping unit.
4. The output grid cells (100 m X 100 m, 500 m X 500 m, and 1000 m X 1000 m) correspond to output maps at scales of 1:50,000, 1:250,000, and 1:500,000 respectively, with 0.2 cm minimum mapping units.

5. The relationships (transformations) among the four data bases, i.e., the aggregation procedures will be different for different types of information. For example, for the Landsat information either a sampling or a linear combination (averaging) procedure will be utilized to generate a 100 m X 100 m, 500 m X 500 m, and a 1000 m X 1000 m cell from the 50 m X 50 m original cell. For areal extent and for line information other aggregation criteria will be utilized.

The Bolivian scientists indicated that the purpose of this information system is:

1. To provide basic cartographic information.
2. To integrate and to manage more effectively the natural resources, environmental factors and socio-economic variables of the country.
3. To provide more efficient means to transfer new technology within the country at the national, departmental and local levels.
4. To help identify what information is lacking, particularly at larger scales.
5. To provide basic resource information to decision makers and general public.

DIGITAL LANDSAT MOSAIC

The cartographic grid base for the geographic information system of Oruro will be created by a digital Landsat mosaic composed by seven (7) images. The 7 Landsat frames in CCT format will be provided by ERTS/GEOBOL (14-800 BPI tapes) in the Brazilian CCT format.

	Area Name	Scene ID	Lat., Long.	Date
1.	Desaguadero	277251-132714	17°22'S, 68°06'W	9/8/77
2.	Salar de Coipasa	277233-132841	18°46'S, 68°23'W	8/21/77
3.	Salar de Empexa	277233-132906	20°13'S, 68°44'W	8/21/77
4.	Oruro	176157-131340	17°20'S, 66°51'W	6/5/76
5.	Lago Poopo	176157-131405	18°47'S, 67°12'W	6/5/76
6.	Salar de Uyuni	277232-132326	24°14'S, 67°19'W	8/20/77
7.	Sucre	279167-133408	18°46'S, 65°41'W	6/16/79

ERTS/GEOBOL will also provide the Black and White photographic products (1:250,000 scale) of these seven Landsat frames in bands 5 and 7 with marks indicating the geographic coordinates (latitude and longitude) of 20-30 control points per frame. The control points will consist of easily recognized features on the images and the geographic coordinates will be obtained from the 1:50,000 topographic maps.

The Landsat data will be resampled to a 50 m pixel and geometrically corrected (precision registration) using the available control points. The resulting digital mosaic will be transformed to an Albers (equal area) projection using 12°S and 20°S as Standard Parallels, and 64°W as the Standard Meridian. Ing. Oscar Tórrez will prepare a document containing the technical justification for using the Albers projection.

The mosaic will contain either the four Landsat spectral bands or at least three bands (4, 5 and 7). The Bolivian scientists have indicated that if it is possible band 6 should also be included.

DATA BASE ELEMENTS

The information will be input and stored in a grid-cell format. The different elements (layers) of the system will consist of (in order of priority):

Layer (element) #	Information Content
1	Landsat MSS 4
2	Landsat MSS 5
( )	(Landsat MSS 6)
3	Landsat MSS 7
4	Dept., Province and Canton boundaries
5	Elevation
6	Slope
7	Aspect (azimuth)
8	Land cover/land use (transportation)
9	Soils
10	Hydrology (Watershed boundaries)
11	Geology
12	Geomorphology
13	Climatology
14	Socio-economic space

Ing. Carlos Valenzuela brought the following maps to Purdue:

- Land cover/land use map of Bolivia, 1:1,000,000, 4 parts.
- Landsat photomosaic of Bolivia, 1:2,000,000.
- Mineralized belts map of Bolivia, 1:1,000,000.
- Metalogenesis of the Bolivian Andes, 1:1,000,000.
- Lineaments and Intrusives maps, 1:1,000,000.

- Geologic map of Bolivia, 1:1,000,000.
- Land complex map of Bolivia, 1:1,000,000
- Land complex map of Oruro, 1:500,000
- 7 Geologic-Lithologic maps of Oruro, 1:250,000.
- 7 Mineralogic maps of Oruro, 1:250,000.
- 1 Isoyets (precipitation) map of Oruro, 1:1,000,000.
- 7 Hydrologic maps of Oruro, 1:250,000 (Watersheds)
- 7 Geomorphologic maps of Oruro, 1:250,000.
- 1 Geomorphologic legend description.
- 7 Soils maps of Oruro, 1:250,000.
- 7 Land use maps of Oruro, 1:250,000.
- 1 Geologic crossection of Cerro Pahua.
- 7 Topographic maps of Oruro, 1:250,000:
  Corocoro 19-7, Cochabamba 19-8, Corque 19-11,
  Unicia 19-12, Salinas de Carci Mendoza 19-15,
  Rio Mulato 19-16, Nevados Payachata 19-10.

ERTS/GEOBOL will send a map (1:500,000) showing the political boundaries of the Oruro Department including the Province and Canton boundaries. There are 10 provinces and 132 cantones in Oruro.

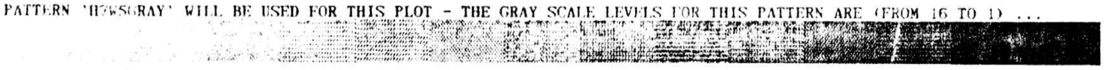
The topographic information (elevation) will be digitized for input into the system from the 1:250,000 topographic maps which have a 100 m contour interval. However, ERTS/GEOBOL will generate a simplified version of the 1:250,000 topographic maps showing only the major contour lines, i.e., every 500 meter interval for steep areas and every 100 meters for the flat areas.

For the climatological information, since it is in a point-data format, ERTS/GEOBOL will generate a gridded data set using the SYMAP Program.

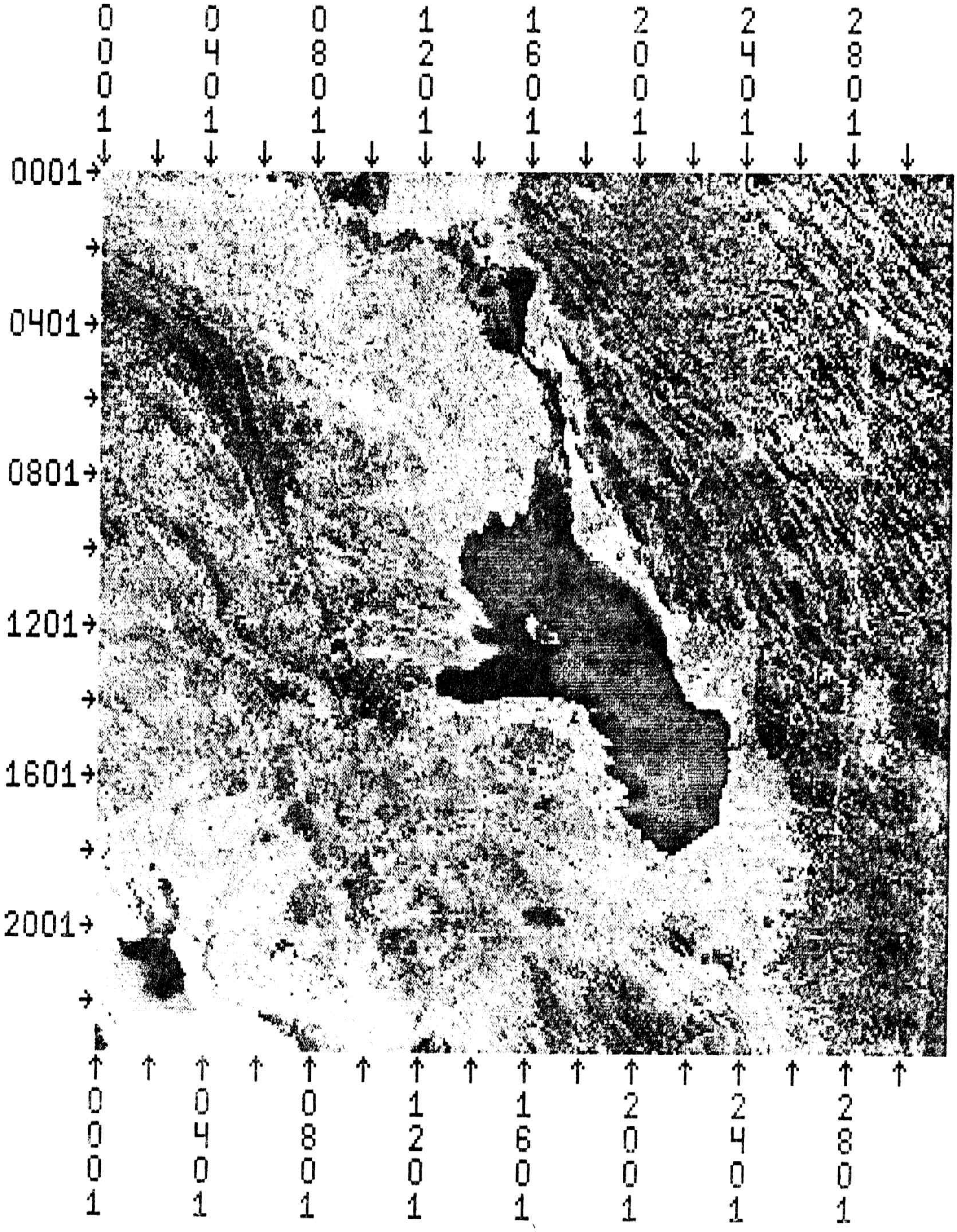
ERTS/GEOBOL suggested that if possible, the transportation and mines location information should be part of the land use layer. They also decided to have 256 different aspect directions at 1.4^{o} intervals, i.e. 360^{o}.

APPENDIX H

HALF-TONE PATTERN 'H7W5GRAY' WILL BE USED FOR THIS PLOT - THE GRAY SCALE LEVELS FOR THIS PATTERN ARE (FROM 16 TO 1) ...



LARS Run Number 76022400 Lago Poopo



LARS FORM - 17D

DATA STORAGE TAPE FILE

Lago Poopo

RUN NUMBER	76022400	FLIGHTLINE ID	540913140 BOLI
DATE TAPE GENERATED	SEPT 17,1980	DATE DATA TAKEN	6/ 5/76
TAPE NUMBER	3769	TIME DATA TAKEN	0814 HOURS
FILE NUMBER	1	PLATFORM ALTITUDE	3062000 FEET
LINES OF DATA	2340	GROUND HEADING	190 DEGREES
SECONDS OF DATA	28.65	FIELD OF VIEW	0.270 RADIANS
MILES OF DATA	100.50	DATA SAMPLES PER CHANNEL PER LINE	3176
LINE RATE	81.68 LINES/SEC	SAMPLE RATE	0.09 MILLIRADIANS
FRAME CENTER LATITUDE	-18.78	FRAME CENTER LONGITUDE	67.21

SPECTRAL BANDWIDTH IN MICROMETERS..

CHAN	LOWER	UPPER	CHAN	LOWER	UPPER	CHAN	LOWER	UPPER
(1)	0.50	0.60	(2)	0.60	0.70	(3)	0.70	0.80
(4)	0.80	1.10	(5)			(6)		
(7)			(8)			(9)		
(10)			(11)			(12)		
(13)			(14)			(15)		
(16)			(17)			(18)		
(19)			(20)			(21)		
(22)			(23)			(24)		
(25)			(26)			(27)		
(28)			(29)			(30)		

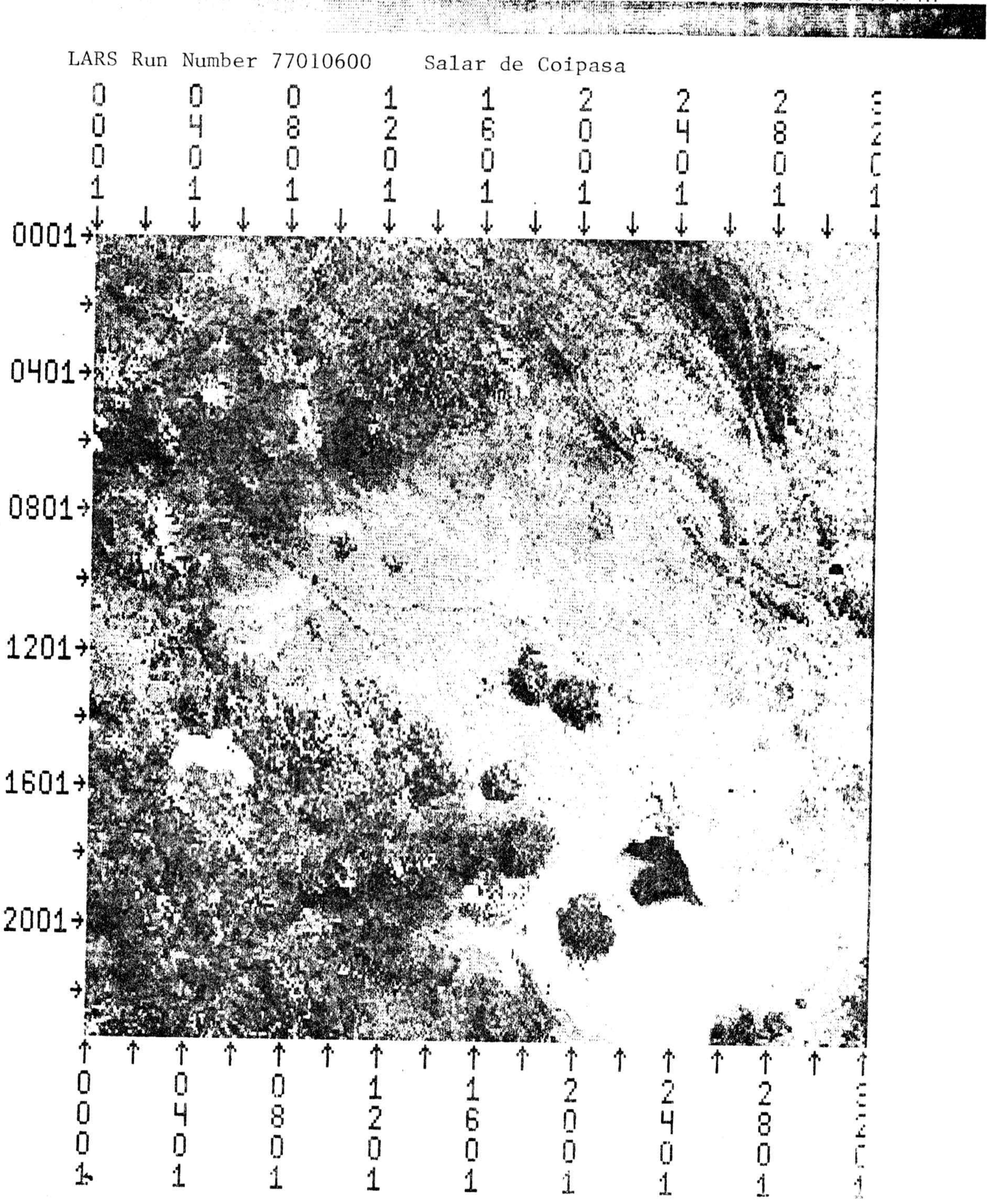
DATA TAPE COMMENTS...

RUN CONDITIONS AND COMMENTS -- LINES 1 - 2340/1 COLUMNS 1 - 3176/1.

WP-265 ACNT-659

HALF-TONE PATTERN 'H/WSGRAY' WILL BE USED FOR THIS PLOT - THE GRAY SCALE LEVELS FOR THIS PATTERN ARE (FROM 16 TO 1) ...

LARS Run Number 77010600 Salar de Coipasa



LARS FORM - 17D

DATA STORAGE TAPE FILE

Salar de Coipasa

RUN NUMBER................. 77C10600
DATE TAPE GENERATED..... SEPT 17,1980
TAPE NUMBER..................... 3768
FILE NUMBER..................... 1
LINES OF DATA................... 2340
SECONDS OF DATA................. 28.65
MILES OF DATA................... 100.50
LINE RATE........... 81.68 LINES/SEC
FRAME CENTER LATITUDE.......... -18.76

FLIGHTLINE ID......... 293913284 BOLI
DATE DATA TAKEN................ 8/21/77
TIME DATA TAKEN............ 0828 HOURS
PLATFORM ALTITUDE......... 3062000 FEET
GROUND HEADING............ 190 DEGREES
FIELD OF VIEW.......... 0.273 RADIANS
DATA SAMPLES PER CHANNEL PER LINE 3208
SAMPLE RATE........ 0.09 MILLIRADIANS
FRAME CENTER LONGITUDE.......... 68.39

SPECTRAL BANDWIDTH IN MICROMETERS..

CHAN	LOWER	UPPER	CHAN	LOWER	UPPER	CHAN	LOWER	UPPER
(1)	0.50	0.60	(2)	0.60	0.70	(3)	0.70	0.80
(4)	0.80	1.10	(5)			(6)		
(7)			(8)			(9)		
(10)			(11)			(12)		
(13)			(14)			(15)		
(16)			(17)			(18)		
(19)			(20)			(21)		
(22)			(23)			(24)		
(25)			(26)			(27)		
(28)			(29)			(30)		

DATA TAPE COMMENTS...

RUN CONDITIONS AND COMMENTS -- LINES 1 - 2340/1 COLUMNS 1 - 3208/1.

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HALF-TONE PATTERN 'H7W5GRAY' WILL BE USED FOR THIS PLOT - THE GRAY SCALE LEVELS FOR THIS PATTERN ARE (FROM 16 TO 1) ...
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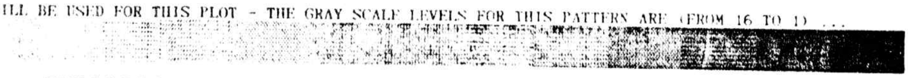
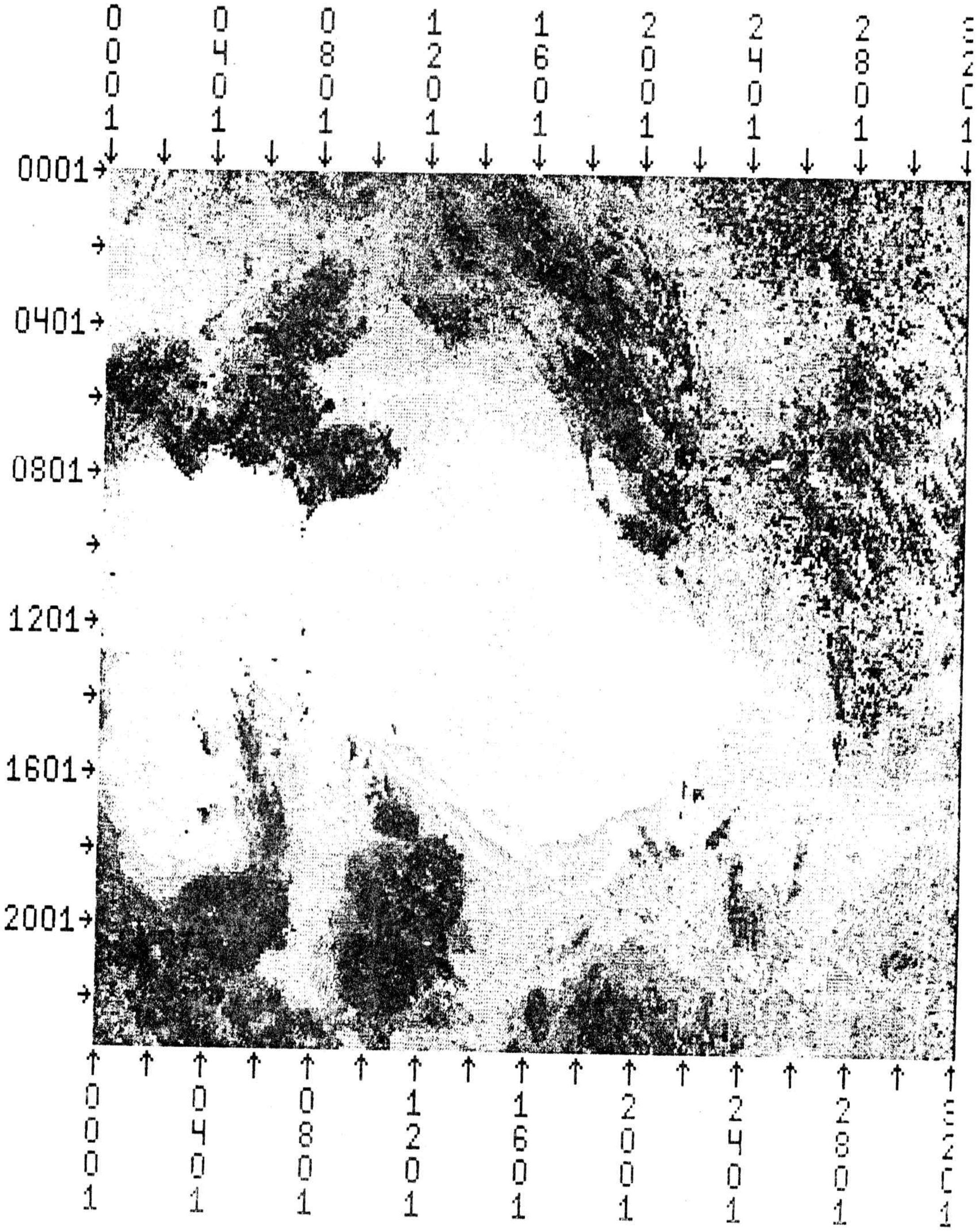


LARS Run Number 77010300 Salar de Uyuni



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FORM - 178

                                   DATA STORAGE TAPE FILE
                                   ----------------------        Salar de Uyuni

RUN NUMBER................. 77010300       FLIGHTLINE ID......29381232    BOVI
DATE TAPE GENERATED... SEPT  3,1980       DATE DATA TAKEN............ 8/20/77
TAPE NUMBER..... 2868    FILE...  1       TIME DATA TAKEN........ 0823 (LST)
LINES OF DATA................. 2340       PLATFORM ALTITUDE.......... 3062000
SECONDS OF DATA.......... 28.65 SEC       GROUND HEADING........ 190 DEGREES
AREA   E-W   99 NM      N-S  100 NM       FIELD OF VIEW 11.43 DEG  0.1995 RAD
LINE RATE.......... 81.68 LINES/SEC       DATA SAMPLES/LINE/CHANNEL..... 3208
TIME DATA WAS TAKEN..... 1323 (GMT)       SAMPLE RATE      0.0622 MILLIRADIANS
SUN ELEVATION.......... 33  DEGREES       LAT. AT FRAME CENTER..... 20 D 14'S
SUN AZIMUTH............ 059 DEGREES       LONG. AT FRAME CENTER... 067 D 19'W
PATH AND ROW IDENTIFIER....               LAT. AT NOMINAL CENTER..  20 D 13'S
DAY SINCE LAUNCH..............  938       LONG. AT NOMINAL CENTER..067 D 22'W
SCENE/FRAME ID........ 2938-1323200       RUN CENTER....   67D 19'W/-20D 13'N
FRAME ID................... 2AF30000       AQUISITION SITE........
STRIP ID....................... 0000

SUN CALIBRATION DATA............          HI GAIN BAND 2....................
HI GAIN BAND 1..................          RECORDED DATA.....................
LINE LENGTH ADJUST.............. *        COMPRESSED DATA................... *
DIRECT DATA..................... *        DECOMPRESSION..................... *
CALIBRATION WEDGE...............          CALIBRATION....................... *

SPECTRAL BAND LIMITS IN MICROMETERS
-----------------------------------

      CHAN    LOWER    UPPER    CHAN    LOWER    UPPER    CHAN    LOWER    UPPER
      ----    -----    -----    ----    -----    -----    ----    -----    -----

      (1)     0.50     0.60     (2)     0.60     0.70     (3)     0.70     0.80
              ----     ----             ----     ----             ----     ----
      (4)     0.80     1.10     (5)                       (6)
              ----     ----             ----     ----             ----     ----
      (7)                       (8)                       (9)
              ----     ----             ----     ----             ----     ----
      (10)                      (11)                      (12)
              ----     ----             ----     ----             ----     ----

RUN CONDITIONS AND COMMENTS--  LINES    1 - 2340/1.  COLUMNS    7 - 3208/1.
WP-260      ACNT-659
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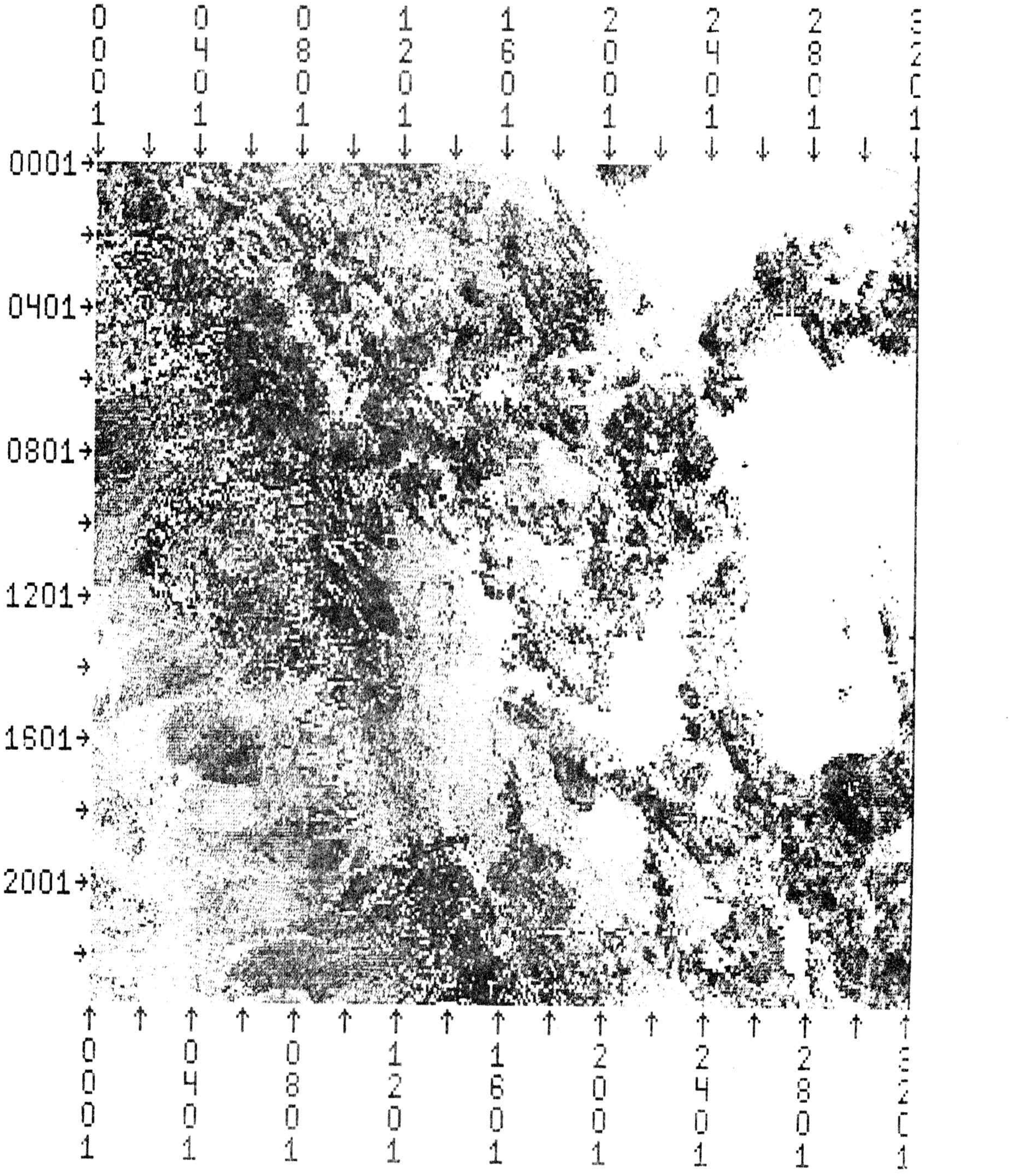
HALF-TONE PATTERN 'H7W5GRAY' WILL BE USED FOR THIS PLOT - THE GRAY SCALE LEVELS FOR THIS PATTERN ARE (FROM 16 TO 1) ...

LARS Run Number 77010700 Salar de Empexa



LARS FORM - 170

DATA STORAGE TAPE FILE

Salar de Empexa

RUN NUMBER.................	77010700	FLIGHTLINE ID.........	293913290 BOLI
DATE TAPE GENERATED.....	SEPT 17,1980	DATE DATA TAKEN...............	8/21/77
TAPE NUMBER....................	3770	TIME DATA TAKEN............	0829 HOURS
FILE NUMBER......................	1	PLATFORM ALTITUDE.........	3062000 FEET
LINES OF DATA..................	2340	GROUND HEADING............	190 DEGREES
SECONDS OF DATA...............	28.65	FIELD OF VIEW..........	0.273 RADIANS
MILES OF DATA.................	100.50	DATA SAMPLES PER CHANNEL PER LINE	3208
LINE RATE...........	81.68 LINES/SEC	SAMPLE RATE.......	0.09 MILLIRADIANS
FRAME CENTER LATITUDE.........	-20.21	FRAME CENTER LONGITUDE.........	68.74

SPECTRAL BANDWIDTH IN MICROMETERS..

CHAN	LOWER	UPPER	CHAN	LOWER	UPPER	CHAN	LOWER	UPPER
(1)	0.50	0.60	(2)	0.60	0.70	(3)	0.70	0.80
(4)	0.80	1.10	(5)			(6)		
(7)			(8)			(9)		
(10)			(11)			(12)		
(13)			(14)			(15)		
(16)			(17)			(18)		
(19)			(20)			(21)		
(22)			(23)			(24)		
(25)			(26)			(27)		
(28)			(29)			(30)		

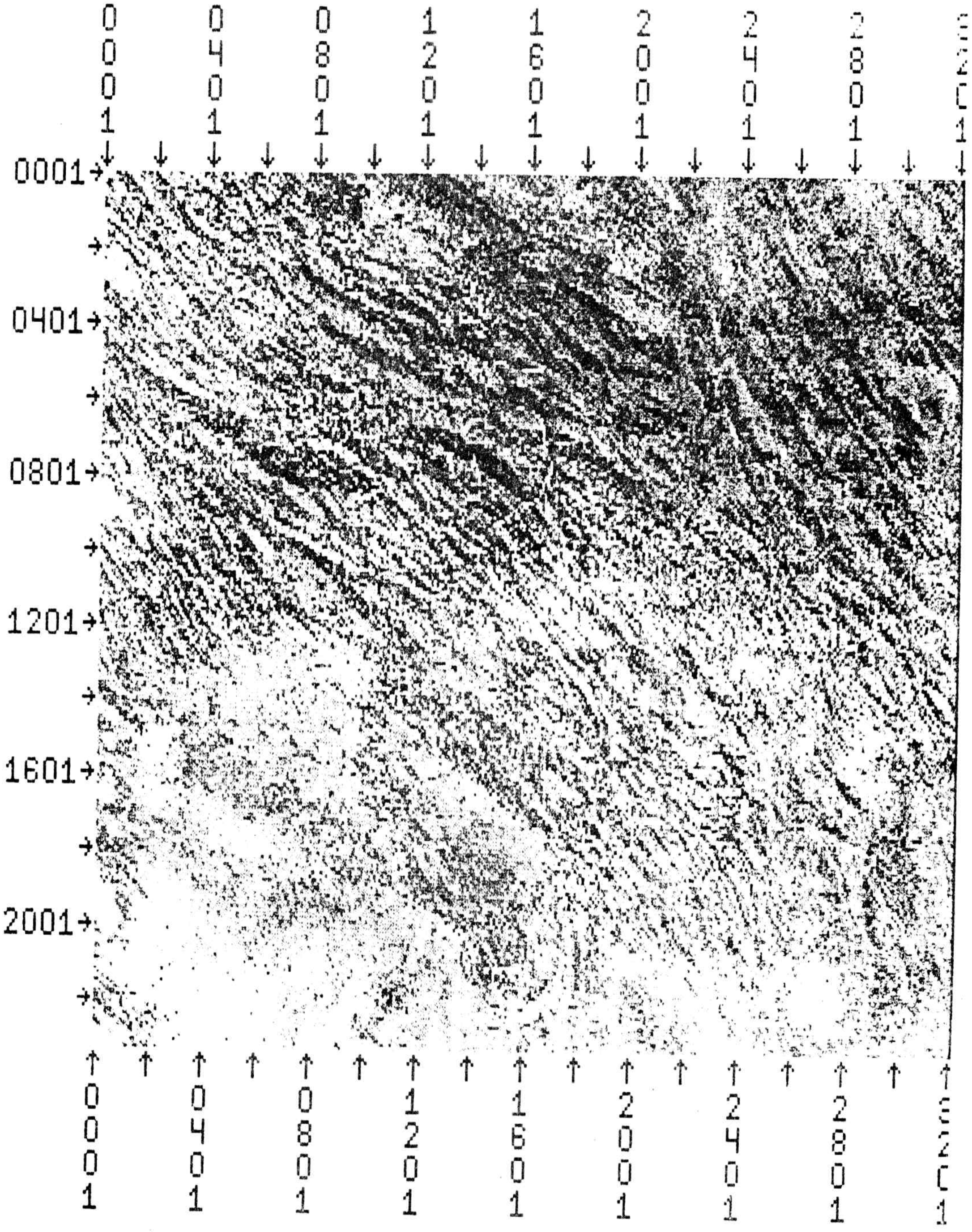
DATA TAPE COMMENTS...

RUN CONDITIONS AND COMMENTS -- LINES 1 - 2340/1 COLUMNS 1 - 3208/1.

WP-266 ACNT-659

HALF-TONE PATTERN 'H7W5GRAY' WILL BE USED FOR THIS PLOT - THE GRAY SCALE LEVELS FOR THIS PATTERN ARE (FROM 6 TO 1) ...

LARS Run Number 79005800 Sucre



LARS FORM - 17D

DATA STORAGE TAPE FILE

Sucre

RUN NUMBER.................. 79005800

DATE TAPE GENERATED..... SEPT 17,1980

TAPE NUMBER...................... 3762

FILE NUMBER....................... 1

LINES OF DATA.................... 2340

SECONDS OF DATA.................. 28.65

MILES OF DATA.................... 100.50

LINE RATE............ 81.68 LINES/SEC

FRAME CENTER LATITUDE......... -18.76

FLIGHTLINE ID......... 660113340 BOLI

DATE DATA TAKEN............... 6/16/79

TIME DATA TAKEN............ 0834 HOURS

PLATFORM ALTITUDE........ 3062000 FEET

GROUND HEADING............ 190 DEGREES

FIELD OF VIEW.......... 0.273 RADIANS

DATA SAMPLES PER CHANNEL PER LINE 3208

SAMPLE RATE....... 0.09 MILLIRADIANS

FRAME CENTER LONGITUDE......... 65.69

SPECTRAL BANDWIDTH IN MICROMETERS..

CHAN	LOWER	UPPER	CHAN	LOWER	UPPER	CHAN	LOWER	UPPER
(1)	0.50	0.60	(2)	0.60	0.70	(3)	0.70	0.80
(4)	0.80	1.10	(5)			(6)		
(7)			(8)			(9)		
(10)			(11)			(12)		
(13)			(14)			(15)		
(16)			(17)			(18)		
(19)			(20)			(21)		
(22)			(23)			(24)		
(25)			(26)			(27)		
(28)			(29)			(30)		

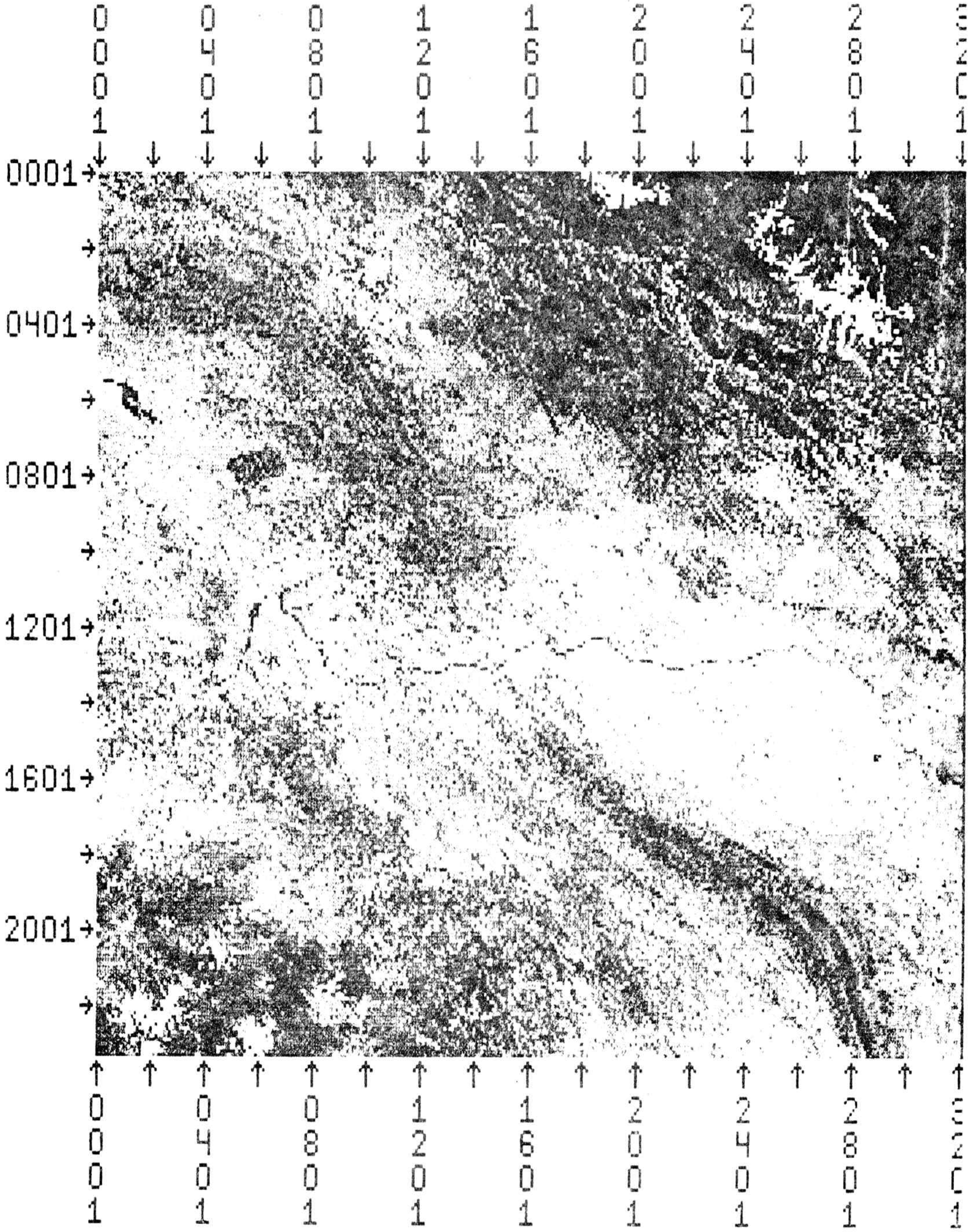
DATA TAPE COMMENTS...

RUN CONDITIONS AND COMMENTS — LINES 1 - 2340/1 COLUMNS 1 - 3208/1.

WP-262 ACNT-659

HALF-TONE PATTERN 'H7W5GRAY' WILL BE USED FOR THIS PLOT - THE GRAY SCALE LEVELS FOR THIS PATTERNS ARE (FROM 16 TO 1 ...

LARS Run Number 77010500 Desaquadero



LARS FORM - 17D

DATA STORAGE TAPE FILE

Desaguadero

RUN NUMBER.................. 77010500
DATE TAPE GENERATED..... SEPT 17,1980
TAPE NUMBER..................... 3767
FILE NUMBER....................... 1
LINES OF DATA.................. 2340
SECONDS OF DATA............... 28.65
MILES OF DATA................ 100.50
LINE RATE........... 81.68 LINES/SEC
FRAME CENTER LATITUDE......... -17.36

FLIGHTLINE ID......... 295713271 BOLI
DATE DATA TAKEN.............. 9/ 8/77
TIME DATA TAKEN........... 0827 HOURS
PLATFORM ALTITUDE........ 3062000 FEET
GROUND HEADING........... 189 DEGREES
FIELD OF VIEW.......... 0.273 RADIANS
DATA SAMPLES PER CHANNEL PER LINE 3208
SAMPLE RATE....... 0.09 MILLIRADIANS
FRAME CENTER LONGITUDE.......... 68.11

SPECTRAL BANDWIDTH IN MICROMETERS..

CHAN	LOWER	UPPER	CHAN	LOWER	UPPER	CHAN	LOWER	UPPER
(1)	0.50	0.60	(2)	0.60	0.70	(3)	0.70	0.80
(4)	0.80	1.10	(5)			(6)		
(7)			(8)			(9)		
(10)			(11)			(12)		
(13)			(14)			(15)		
(16)			(17)			(18)		
(19)			(20)			(21)		
(22)			(23)			(24)		
(25)			(26)			(27)		
(28)			(29)			(30)		

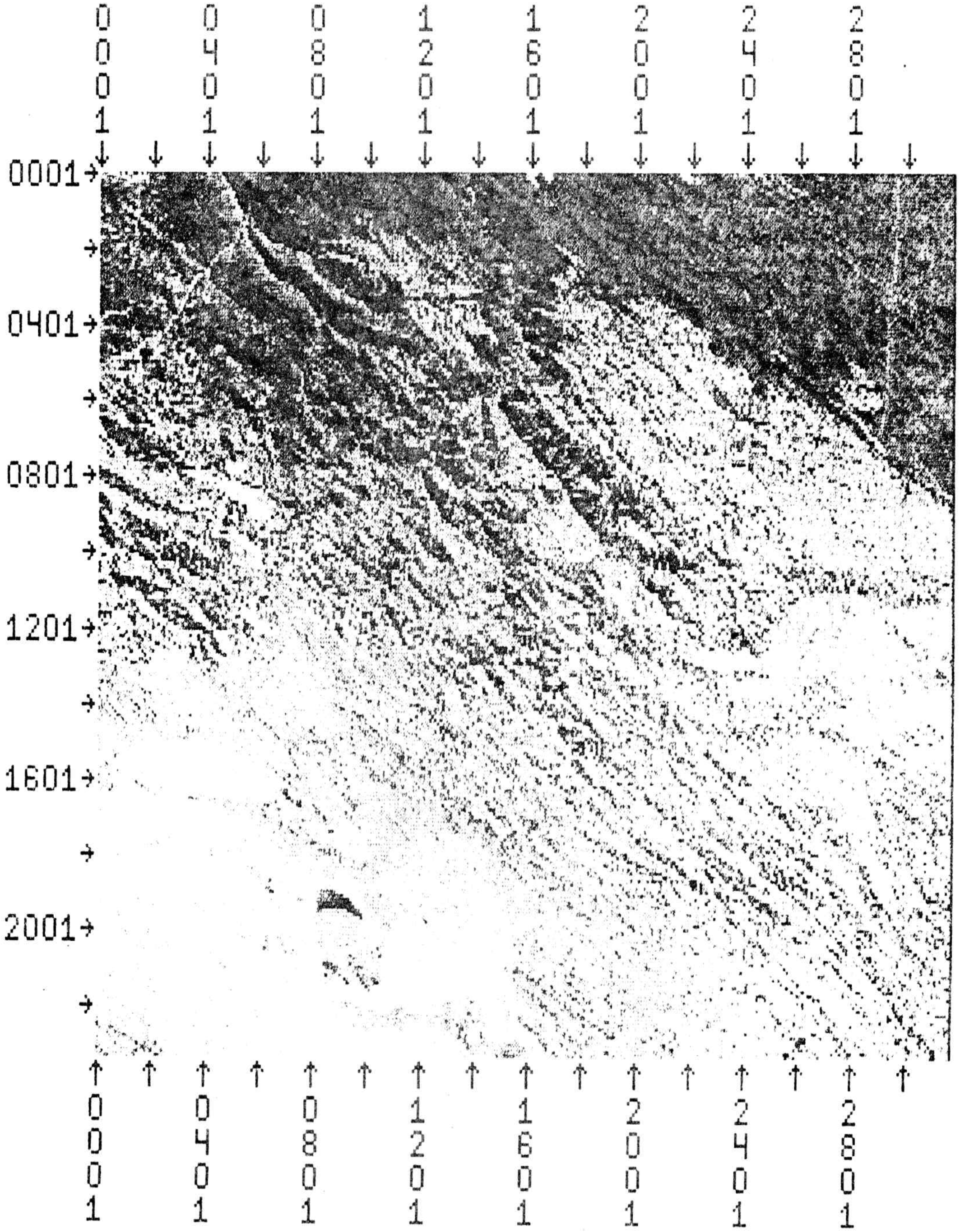
DATA TAPE COMMENTS...

RUN CONDITIONS AND COMMENTS -- LINES 1 - 2340/1 COLUMNS 1 - 3208/1.

WP-263 ACNT-659

HALF-TONE PATTERN 'H7WSGRAY' WILL BE USED FOR THIS PLOT - THE GRAY SCALE LEVELS FOR THIS PATTERN ARE (FROM 16 TO 1) ...

LARS Run Number 76022500 Oruro



LARS FORM - 17D

76

DATA STORAGE TAPE FILE

Oruro

RUN NUMBER	76022500	FLIGHTLINE ID	540913134 BOLI
DATE TAPE GENERATED	SEPT 17,1980	DATE DATA TAKEN	6/ 5/77
TAPE NUMBER	2836	TIME DATA TAKEN	0813 HOURS
FILE NUMBER	3	PLATFORM ALTITUDE	3062000 FEET
LINES OF DATA	2340	GROUND HEADING	189 DEGREES
SECONDS OF DATA	28.65	FIELD OF VIEW	0.270 RADIANS
MILES OF DATA	100.50	DATA SAMPLES PER CHANNEL PER LINE	3176
LINE RATE	81.68 LINES/SEC	SAMPLE RATE	0.09 MILLIRADIANS
FRAME CENTER LATITUDE	-17.33	FRAME CENTER LONGITUDE	66.86

SPECTRAL BANDWIDTH IN MICROMETERS..

CHAN	LOWER	UPPER	CHAN	LOWER	UPPER	CHAN	LOWER	UPPER
(1)	0.50	0.60	(2)	0.60	0.70	(3)	0.70	0.80
(4)	0.80	1.10	(5)			(6)		
(7)			(8)			(9)		
(10)			(11)			(12)		
(13)			(14)			(15)		
(16)			(17)			(18)		
(19)			(20)			(21)		
(22)			(23)			(24)		
(25)			(26)			(27)		
(28)			(29)			(30)		

DATA TAPE COMMENTS...

RUN CONDITIONS AND COMMENTS -- LINES 1 - 2340/1 COLUMNS 1 - 3176/1.

WP-261 ACNT-834