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GLOBAL CHANGE RESEARCH PROGRAM

NORTH AMERICAN LANDSCAPE CHARACTERIZATION (NALC) - PATHFINDER PROJECT

RESEARCH PLAN

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PROJECT OVERVIEW

Introduction

The North American Landscape Characterization (NALC) project is a component of the National Aeronautics and Space Administration (NASA) Landsat Pathfinder program of experiments to study global change issues. The NALC program is funded principally by the U.S. Environmental Protection Agency's (EPA's) Office of Research and Development (ORD) Global Warming Research Program (GWRP), and by the U.S. Geological Survey EROS Data Center.

The purpose of the project is to produce land cover and land cover change data products at a 3.2-to-5.8 hectare (8.0-14.2 acre) spatial resolution across a major portion of the North American continent (Central America, Mexico, Caribbean and Hawaiian Islands, and the United States). The NALC - Pathfinder is designed to contribute to an important objective of the U.S. Global Change Research Program by "documenting global change." In support of the EPA's GWRP, NALC will assist in providing primary land cover type and extent data for use in national inventories of terrestrial carbon stocks and trace greenhouse gas (methane, nitrogen compounds) emissions, and support the carbon cycle and trace gas dynamics assessment objectives of the Intergovernmental Panel on Climate Change (Anonymous 1993). Principal U.S. NALC collaborators include the EPA's Environmental Monitoring Systems Laboratory at Las Vegas, Nevada (EMSL-LV), the U.S. Geological Survey's EROS Data Center (EDC) in South Dakota, and NASA Ames Research Center at Moffett Field, California.

EPA research funds will be made available to support application project research beginning in Fiscal Year (FY) 1993. Application project research will focus on the development of land cover and land cover change digital data base products and on the assessment of product accuracies. Two remote sensing consortia are being developed to provide application project support in Mexico and Central America. Funding for application project research in the United States will be determined on a competitive basis beginning in Fiscal Year 1995. A total of seven funding assistance agreements are expected to be initiated in support of the NALC - Pathfinder project by 1996.

The objectives of the NALC project are to produce standardized remote sensing data sets, develop standardized analysis methods, and derive standardized land cover change products for the majority of the North American continent. All data, methods and derivative products will be made available to the global change research community. Data will be vended at the cost of duplication and distribution. All data and products will be archived by EDC and listed in their Information Management System (IMS) so as to provide user access and data distribution support.

Information about NALC products and ordering may be obtained from: Customer Services, EROS Data Center, USGS, Sioux Falls, SD, 57198, (605) 594-6151.

Areas of Coverage

The NALC project includes all of the North American continent, defined as the area north of the Panama-Colombia border including the Caribbean and the Hawaiian Islands. Due to funding restraints and limited Landsat data holdings in U.S. archives, NALC is currently not funding the assembly of standard NALC data sets for Canada. Canadian archives contain an extensive collection of Landsat Multispectral Scanner (MSS) data from the 1990's, 1980's, and 1970's that could be used in support of a NALC/Canada effort. Currently, work is under way on a Great Lakes Watershed Pilot Study under the leadership of the Canada Centre for Remote Sensing (CCRS). The future expansion of NALC to other priority watershed locations in Canada will be dependent on the results of the CCRS Great Lakes Watershed Pilot Study.

Satellite Data Acquisition

Satellite data used in the NALC project include Landsat MSS data from the years of 1991, 1986, and 1973, plus or minus one year (whenever possible). MSS data are the principal source of satellite measurements for the NALC program. This is for several reasons, including the 20 year MSS digital data archive and the relatively low data costs as compared to Landsat Thematic Mapper (TM) or SPOT Multi-Spectral (MS) data. A total of 803 Landsat MSS scenes were acquired during 1992 to help complete the twenty year MSS data archive. Data collections for the 1990's epoch included: Mexico (102 scenes); Central America (34 scenes); the Caribbean islands (48 scenes); Alaska (182 scenes); Western U.S. (138 scenes); Chesapeake Bay Watershed (18 scenes); Eastern and Southern U.S. (142 scenes); Midwest and Great Plains (131 scenes); and Hawaiian islands (8 scenes). In addition to the 803 MSS scenes acquired for 1990's by NALC, a comprehensive review of the Landsat

MSS archive has been conducted, and historical MSS data have been selected from the 1970's and 1980's to complement the 1990's data acquisitions.

Standardized Data and Products

Standardized data sets used in the NALC project feature Landsat MSS triplicate images that have been georeferenced and presented in earth coordinates. In addition, image to image coregistration between the triplicate image scenes has been stressed to provide high quality and standard data sets for land cover change analysis. The NALC standard triplicate data sets will include the following: 1) Coregistered/georeferenced Landsat MSS triplicates; 2) Digital Elevation Model (DEM) data; 3) spectral cluster or categorized data coverages corresponding to individual NALC triplicate MSS scenes; and 4) change detection images. All data sets will be clipped to the Landsat World Reference System 2 (WRS2) image sampling frame. In the case of the 1970's images, which conform to the World Reference System 1 sampling frame, multiple scenes are being assembled and clipped to the WRS2 sample frame boundaries to provide complete coverage.

An important aspect of the NALC project is the generation of standardized data products for the North American continent. These derivative products include: A nearly border-to-border land cover (vegetation) type categorization for priority North American locations using the 1990's MSS imagery; and land cover change data from the early 1970's to the early 1990's. Land cover change data sets will be processed only for those areas where vegetation change has occurred between successive dates of the triplicate. For example, scene by scene change detection analysis will yield two products: 1) A change detection image indicating the locations of change within a scene between 1990's to 1980's and 1990's to 1970's; and 2) a raster data coverage identifying the land cover type(s) that existed at specific locations and that had undergone change.

It should be noted that the CCRS Great Lakes Watershed Pilot Study differs from non-Canadian NALC project activities in that the Great Lakes Pilot will result in the development of a 50-meter MSS mosaic data product. This study is actually a parallel project being conducted in association with NALC and using NALC products. Subsequent to the completion of the pilot, the CCRS will evaluate the utility of a NALC type effort for Canada. EPA is hopeful that the Great Lakes pilot will eventually develop into a larger NALC/Canada effort.

Methods Development

Specific issues related to development of NALC remote sensing standard methods have been addressed. Methods issues include determining: 1) The time periods when satellite data should be acquired for most of North America (by path/row image scenes); 2) the characteristics of automated Landsat MSS scene georegistration and image-to-image coregistration; 3) the procedures necessary to develop cloud reduced MSS image composite products; 4) the algorithm for spectral clustering; 5) standard methods development for land cover class labeling; 6) image difference algorithms, post-categorization procedures, and standard methods to be used for land cover change analyses; 7) data indexing/archiving and metadata Information Management Systems (IMS); 8) NALC Quality Assurance/Quality Control (QA/QC) procedures; 9) accuracy assessment methods; 9) land cover classification system; and 10) Landsat Thematic Mapper (TM) swath data acquisition and data processing methods.

Whenever possible NALC will utilize existing remote sensing data analysis methods that have wide acceptance in the remote sensing community. A specific goal is to draw upon the most conservative methods that will accomplish NALC data processing objectives. This emphasis towards conservative methods is to provide standard methods that can be employed by as many researchers as possible. However, there are numerous remote sensing methods development issues that will require new approaches or significant improvement to existing methods. Methods currently under development include: 1) The automated georeferencing and coregistration of Landsat MSS imagery; 2) the development of accuracy assessment procedures for large area accuracy assessment; 3) the development of a NALC land cover classification system; and 4) the development of Landsat TM swath data acquisition and data processing methods.

Project Schedule

The schedule for the assembly of NALC triplicates and application project starts is presented in Table 1.

TABLE 1.

SCHEDULE FOR TRIPLICATE ASSEMBLY AND APPLICATION PROJECT STARTS

Project Schedule

The following schedule is based on continued-level funding through FY 98.

TRIPLICATE ASSEMBLY		SCENES	APPLICATION START
1993	Mexico	102	1994
	Chesapeake Bay Watershed	18	"
	Caribbean	48	"
	Central America	34	"
		202	
1994	Alaska	182	1995
	Hawaii	8	"
	Western U.S.	138	"
		328	
1995	Midwest and Great Plains	131	1996
	Eastern-Southern U.S.	142	"
		273	

Global Change Science Issues

The principal clients of the NALC-Pathfinder project are the U.S. Global Change Research Program (USGCRP), and the U.S. EPA's Global Warming Research Program (GWRP). NALC fulfills an important goal of the USGCRP by "Documenting Global Change". An important objective of the USGCRP is to document global change through the establishment of an integrated, comprehensive, long term program of observing and analyzing earth systems change on a global scale (Committee on Earth and Environmental Sciences 1993). The NALC project is part of a larger global effort known as the Landsat Pathfinder Science Working Group. Other companion projects included in the Landsat Pathfinder series are being conducted in: Amazonia (NASA), Central Africa (NASA), S.E. Asia (NASA/EPA), Coastal Brazil (EPA) and Eastern Europe (NASA).

The Environmental Protection Agency's GWRP research projects will benefit from NALC data products focused on science issues related to carbon and trace greenhouse gas fluxes. The carbon measurements will be used in global climate change models to refine predicted changes in land cover distributions. These contributions will be used to estimate changes in carbon stocks and carbon fluxes from the terrestrial system to the atmosphere, and in attempts to identify carbon sources and sinks.

NALC products will provide inventories of the current status and changes over the past 20 years for specific land cover types. These data will be used by global change research scientists in combination with literature values or new field measurement data, to calculate standing carbon stocks and estimate carbon and trace greenhouse gas fluxes over the past 20 years. NALC land cover data base products could also be applied in the identification of North American locations suitable for growing land cover types (vegetation) to capture or sequester carbon.

The general change in carbon abundance or flux estimates for carbon in North America over the past 20 years will be based on the changes in land cover from one type to another (i.e., forest cover or "woody" to agriculture or "developed land"). NALC will also attempt to categorize the different age classes during the process of forest regrowth. These data will be particularly important for providing more accurate estimates of carbon content for individual forest stands.

Digital data products to be provided in support of carbon and greenhouse gas studies include the NALC "triplicate data sets", and nearly border-to-border land cover (LC) and LC-change data for priority locations in North America. NALC standard land cover and land cover change digital data base products will have both immediate and future applications in support of global change science issues. The 1991 +/- one year border-to-border, land cover product for North America will have the following applications to: 1) Provide data input for the calculation of standing carbon stocks; 2) provide data to determine areas of anthropogenic change in land cover; and 3) provide a baseline data set to evaluate future shifts in land cover attributable to future changes in global climate.

The importance of land cover type data for calculating carbon stocks is illustrated in the following equation (Sheffner et al. 1993).

Total North American Carbon (LCi) = A (LCi) x C (LCi)
for land cover type "i"

where:

A (LCi) = Area of land cover type i, and

C (LCi) = Carbon per unit area or carbon density for land cover type i

The level of confidence of total NALC North American carbon estimates will be no greater than the uncertainty associated with either or both of the above terms, A or C. A general consensus among researchers is that the uncertainty associated with the area term, is at least as great as that of the carbon stock per unit area or carbon density measure for a given land cover type (Skole 1993). Also, the amount of carbon contained in forest land cover is much greater than other land cover types. Hence, measurement of forest cover types has the highest priority (Houghton et al. 1992).

Current estimates of deforestation in the United States are largely based on statistics data compiled by the U.S. Forest Service and state government forest management agencies. Most of these statistics provide limited information on the spatial distribution of forest resources. Although important data (e.g., timber type and diameter breast height, DBH) for the calculation of carbon stocks are typically compiled, data from state inventories are not easily accessed and inventory data are not typically collected for private land holdings. South of the U.S. border, forest statistical data in Mexico and the Central American countries are, for the most part, unavailable.

To provide a consistent source of data to support the study of global deforestation rates and to provide data inputs to greenhouse warming and global vegetation models requires a project such as NALC. Scientists have been utilizing NOAA Advanced Very High Resolution Radiometer (AVHRR) data for related purposes. AVHRR data have and will continue to provide an excellent source of data for global change research. The temporal frequency of data collections (daily), the low data volume, and inexpensive costs of acquiring these data contribute to its utility. EPA global change modelers addressing terrestrial systems response and vegetation redistribution find the 1.1 km by 1.1 km spatial resolution of AVHRR data applicable to their models which require data input in one-degree longitude by one-degree latitude cells. Although AVHRR data meet many of the remote sensing data input requirements for current global change modeling efforts, serious problems can occur when limited to only one remote sensing data source.

An important factor in evaluating the utility of any data source being considered as data input for monitoring, inventory, or modeling studies is the accuracy and precision associated with the data. In remote sensing studies data are validated as to their accuracy and precision in one of three ways. The first two methods involve comparing remote sensing results to in situ field measurements or comparing the results to another remote sensing data source of known accuracy and precision. The third method involves comparing two remote sensing data results of unknown accuracy and precision. By evaluating the agreement between two data sets, a quantitative evaluation of data quality can frequently be made. It is best to employ one of these three approaches, as there is a significant potential for error when data are assumed to be accurate when in fact they have not been validated.

An analysis of various remote sensing data types and approaches for monitoring tropical deforestation were evaluated under a NASA-sponsored research project titled "Landsat Tropical Deforestation Project". Results revealed that Landsat Thematic Mapper (TM) and SPOT Multi-Spectral data provide comparable estimates of standing forests (Skole and Tucker 1993). However, when compared to AVHRR results, the AVHRR overestimated the area of tropical forest stands by 40 to 90 percent. A comparison of the rates of tropical deforestation between Landsat and AVHRR data indicated that AVHRR results often overestimated the rates of tropical deforestation by approximately 200 to 400 percent (Skole and Justice 1992).

The NALC data products will provide data of known accuracy and precision to facilitate the evaluation of other commonly used remote sensing data for global change research, e.g., AVHRR. NALC MSS data products will also facilitate the study of sub-kilometer scale science issues, i.e., "patch" sizes and the change or migration of land cover types. In particular the NALC data products will be useful in the study of "landscape pattern change" or "early indicators" of global change, such as induced shifts in biogeographic regions or spatial distribution changes of land cover within a given region. These changes that would not be detected with coarse resolution sensors, and they could have an impact on ecological function prior to migration events.

The Landsat MSS "triplicate data sets" or "triplicates" represent the NALC standard data set. These data sets alone will represent a substantial contribution to the study of global change and will do so well into the next century. In addition to their application in global change research, NALC triplicate data sets will provide an unparalleled data record and will potentially contribute to the study of numerous science issues in North America. Examples of future science applications include: 1) The documentation of changes in biodiversity; 2) contributions to the future mapping of North American biotic community zones; and 3) the analysis of future geographic shifts in vegetative communities related to changes in global climate.

The standard NALC LC-change products will provide important data for global change scientists as they provide a retrospective "picture" or view in time useful in evaluation of a number of important global change science issues. Issues applicable to NALC LC-change products include: 1) The measurement of change in land cover or change in carbon abundance (carbon flux) over the past 20 years; 2) estimating the potential for storing carbon in the form of land cover (carbon sequestration) in North America; and 3) estimating the flux of trace greenhouse gases using change in land cover as an indicator. Carbon and trace greenhouse gas fluxes are defined as the net exchange between terrestrial sinks and the atmosphere over time.

The development of a border-to-border baseline land cover data set for much of North America will potentially be a major accomplishment. The current Landsat Pathfinder series is the first attempt at processing high resolution land cover type data sets for significant portions of the global land mass. Border-to-border baseline triplicate data sets are not currently being developed for Canada. However, subsequent to the completion of the Great Lakes Watershed Pilot study by the CCRS, it is hoped that Canada will embark on a NALC/Canada effort to complete the border-to-border baseline data assembly for North America.

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CHARACTERISTICS OF SENSORS AND

NALC - PATHFINDER DATA SETS

Landsat Program History

The Landsat program of satellites gathered digital Multispectral Scanner (MSS) remote sensor data from July, 1972 through September, 1992. The result is a twenty year time span of data and the opportunity to evaluate earth resources from space.

Because the archive is composed of digital data, these products present a useful source for image processing and analysis. These data will support evaluations of change in landscapes or land cover over time. No other digital archive of similar time length, similar resolution, or of similar potential information content is available for North America.

Landsat data have been indexed and archived in a number of facilities throughout the world including North America. Data collection and indexing has been discontinuous for most areas, however, and has required the NALC Project to select particular years in the past twenty for analysis. These certain years hold many scenes of interest in the archive.

For the United States the historical Landsat MSS data resides at the National Satellite Land Remote Sensing Data Archive (NSLRSDA) at the EROS Data Center. In particular, the years 1973 and 1986 have very complete coverage of North America. They have been selected as focal years to include in the production of NALC-Pathfinder images. The archive from these years, plus or minus a one year period, will provide a unique opportunity to develop a NALC data set for North America.

To assure that high quality MSS data would be available for the current period of time, a major acquisition program was executed. The program involved purchase of MSS coverage for 1992 based on the existing purchase agreement between EDC and EOSAT. From February through September 1992 a number of acquisitions were made. This action successfully populated the archive and will support production of images for the current time period.

Multispectral Scanner (MSS) Data Characteristics

Multispectral Scanner (MSS) instruments have flown on Landsats using the same or similar spectral and spatial resolution. This consistent period of instrument deployment provides a unique opportunity to conduct comparisons over time.

The MSS has four spectral bands or spectral bandpass windows that are measured by detectors. The bands include a green band or band 1 (0.5 - 0.6 um), a red band or band 2 (0.6 - 0.7 um), a near infrared band 3 (0.7 - 0.8 um) and a second near infrared band 4 (0.8 - 1.1 um). Bands 1 through 3 are digitized on a scale of 0 to 127, and band 4 is digitized from 0 to 63. On later Landsats the band labelling was changed so that old system bands 4 through 7 are now new system bands 1 through 4. The new system is used here.

The MSS sensor measures spectral radiance over a nominal instantaneous field of view (IFOV) of approximately 80 m by 80 m. The pixel resolution was resampled to 57 m by 80 m during ground processing as that was the true geometric or spatial resolution. The difference resulted from a systematic over-sampling of radiance along the scan line. This action served to sharpen or convolute the image. The difference between the spectral and spatial resolution has been addressed and corrected in the standard NALC processing procedures by pixel resampling. The different pixel dimensions are rectified in the course of generating the geocoded triplicates, and the resultant output pixels are resampled to 60 m by 60 m. This procedure is described later.

NALC Landsat MSS Triplicate Image Data Sets

A major goal of NALC-Pathfinder was the development of a "triplicate" product of historical and current data from the MSS instruments. The triplicate would include a scene from 1973 plus or minus one year, 1986 plus or minus one year, and 1991 plus or minus one year. The triplicate is a "stack" of three image scenes for each individual path/row scene of North America. The path/row scenes form a world wide coverage that can be indexed via the Landsat World Reference System (WRS). For each individual path/row scene of the WRS for MSS sensor, the areal coverage on the ground is approximately 185 km by 185 km.

The NALC program is dedicated to building coverage of North America in triplicate MSS data sets. From this triplicate product it will be possible to evaluate change between three dates over the last twenty years.

Image Composites

The standard NALC products are to be thirty percent or less cloud covered. In some areas of North America it will not be possible to obtain a given scene that meets the standard. Hence, reduced cloud cover composites (RCCC) will be made from two scenes. Composite scenes will be necessary to provide appropriate land coverage by path/row image scene and to supply similar information for evaluations of change between 1986 and 1991 scenes in a triplicate. This product will be made by EROS Data Center (EDC) and is described later.

Categorized Images of Land Cover

To address variables of interest to Global Change Researchers, it is necessary to process NALC triplicates into derivative products. Of particular utility is the Land Cover (LC) thematic map that displays the land cover types found in a given scene. The land cover classes are keyed to a land cover categorization system of standard design (see section on image categorization for the system).

Evaluations of single-date NALC scenes provide inventory data on land cover or landscape characteristics. Comparisons of two or more dates of NALC scenes allows determination of change in land cover classes.

Change Detection Images

The determination of change in land cover over time is one goal of the GCRP. Comparisons of land cover change between the 1970's, 1980's and 1990's image scenes will be undertaken by NALC. The products are described in the section on change detection.

METHODS AND RESPONSIBILITIES FOR

PRODUCTION OF DATA PRODUCTS

Acquisition of Current Data Products

Landsat MSS data products for use in the NALC - Pathfinder project have already been acquired between February and the end of September, 1992. This effort was initiated early to populate the recent archive with suitable MSS images before the cessation of MSS data acquisition. Past activities by other MSS clients had not resulted in acquisitions on a continental basis for North America. Thus, the NALC project acted quickly to avoid a similar deficiency in the 1992 timeframe.

The acquisition program was developed between USEPA, USGS and EOSAT. EOSAT formerly had copyright on the raw MSS data for a two-year period after acquisition, and they formerly operated much of the system for data collection and initial data processing. Their role diminished with the transfer of the existing processing capability and MSS archive to EDC in March, 1993.

The coordination and implementation of data collection activities involved an Interagency Agreement (IAG) between USGS and USEPA (Appendix V) and subsequent use of the standard USGS-EOSAT agreement covering Landsat data purchases and processing activities.

The MSS data were scheduled for acquisition based on a number of land and cloud-cover criteria. Considerable study was made of historical periods of low cloud-cover acquisitions throughout the NALC area of interest. Details on the seasonality of forest cover and crop cover, the seasonality of snow cover, and the timing of growing or rainy seasons were used to select periods for data acquisition. This effort is further described in Appendix VI.

Identification of Archival Data Products

The MSS triplicate images make use of a 1991 +/- one year period data set and two archival image scenes or "path/rows" from the archive. The archival images were obtained from the National Satellite Land Remote Sensing Data Archive (NSLRSDA) at EROS Data Center in Sioux Falls, South Dakota.

Selection of two historical scenes for each triplicate was made from the 1970's and 1980's archive. The selection has been made by efforts of EMSL-LV, cooperators and EROS Data Center (EDC) personnel. The criteria for selection included: 1) The three scenes should be from similar seasonal periods; 2) they should contain thirty per cent or less cloud cover; 3) one image scene should be from 1973 plus or minus one year; 4) one scene should be from 1986 plus or minus one year; and 5) the images should be of high quality.

The years 1973 and 1986 were selected based on the population of the MSS data archive. A complete or majority coverage of North America was not commonly achieved. These years represent the best examples in terms of data availability.

The main objective is to obtain the highest quality images from the three periods and to have the images match closely in seasonal or phenological time. Naturally, the varying conditions of weather, image collection priorities, population of the archive and other factors detract from this objective. A best effort was made to meet the criteria and produce high quality products.

Image Processing of Triplicate Scene Data Products

A variety of activities are involved in production of the triplicate products from three MSS data scenes. Data processing activities include geometric corrections, radiometric corrections, data formatting, scene-to-ground image registration or "georegistration", image-scene-to-image-scene registration, data indexing and archiving, and data distribution.

An overall objective is to develop an optimal data product for the user. Efforts have been focused to provide a uniform and standard product that resulted from both geometric and radiometric corrections. In general, the corrections were conservative in design and necessary to reduce sources of noise and to present the image as a map-like product. The procedures were intentionally conservative to ensure that they represented approaches with demonstrated capabilities based on widespread current and historical use.

Landsat MSS Data Characteristics

Landsat data have been archived and delivered in a variety of formats over the years. The initial format for purchase was the "X" format. This gave way to the "A" format that included additional processing to yield a partially corrected product. The most recent and current standard is the "P" format.

Landsat MSS data in X format have been corrected for variations in detector gains and offsets. They have also been corrected for line length variations by the addition of extra pixels at regular intervals at the ends of lines.

Additional X format characteristics include a pixel storage format which was band-interleaved-by-pixel. The individual pixels ("n") were stored as pairs (n, n + 1) for the four bands, and the next two pixels were stored (n + 2, n + 3) for each band. The data were also stored in four strips or tracks of approximately 810 to 830 columns. These strips need to be patched together to develop a whole image product.

Landsat MSS data were subsequently stored in A format. These data were available in either band-interleaved-by-line or band-sequential formats. Band-interleaved-by-line format had all the pixels in one scan line (n, ..., n + 3200) stored one band at a time. Band-sequential images stored all the pixel rows and columns, by individual band, as individual files.

Landsat MSS data of current origin are stored as a P format product (band-interleaved-by-line or band-sequential formats). The data have either been rectified with ground-control points or ground-control chips (precision corrected) or without use of ground control reference points in a systematic correction based on satellite orbital characteristic data. The P format data are provided in either Universal Transverse Mercator, Hotine Oblique Mercator, or the Space Oblique Mercator projections.

Due to the variety of formats over the years and the historical nature of the NALC effort, it was necessary to address all these differences and organize processing procedures for them.

For NALC, the systematic corrections applied to the triplicate images by EDC included:

Band-to-band geometric offsets;

Line-length adjustments;

Detector-to-detector radiometric offsets;

Correction for earth rotation during image acquisition;

Non-linear acceleration / deceleration of scanning mirror; and

Satellite ephemeris or orbital characteristics.

Image Processing for NALC MSS Triplicate Production

Background

Restoration of geometric fidelity and accurate registration of entire images, pairs or triplicates of images, or component parts of Reduced Cloud Cover Composites (RCCC) raises important issues. The use of ground control points and image rectification procedures are used to transform the image data to a map projection. The use of ground control point library (GCPLIB) image chips can expedite the process of georeferencing and scene-to-scene registration.

A number of processing procedures have been established to facilitate the production of standard NALC triplicates. These include the systematic radiometric and geometric corrections and precision image-to-map registration. The procedures presented here have been implemented by the EROS Data Center for production of standard triplicates. These standard procedures have been developed from more than twenty-years of experience in the digital processing of Landsat data. A number of these procedures are well known and have been documented in the literature.

The 1970's data selected for use in triplicate production are pre-processed to correct for line length adjustments, variable detector response, band registration, nonlinear mirror-scan velocity, earth-rotational skew, and detector-to-detector offsets. Both the line length adjustments and detector-to-detector offsets require a resampling in the along-scan direction (one-dimensional cubic convolution). The parameters for these systematic radiometric and geometric corrections are derived from the satellite ephemeris and payload correction data. The individual bands are also "destriped" to remove noise due to variable detector response. The resultant product is analogous to the "P" product currently generated by the EROS Digital Image Processing System (EDIPS). In accordance with the Landsat Pathfinder Program concept, the Pathfinder "basic data sets" will be composed of data which have been radiometrically and geometrically processed to the "P" level. NALC triplicates, however, will be processed beyond the "P" level as described below.

Data Acquisition

The generation of NALC triplicates is initiated once the appropriate scenes have been identified by EPA-EMSL and purchased from EDC. EPA staff are responsible for determining all scenes to be purchased, both current and historical acquisitions, in accordance with the scene selection criteria described in a previous section. This process involves searching databases and reviewing browse or microfiche imagery to assess cloud cover and image quality. EPA submits the scene-identification numbers to EDC for the subsequent submission of CCT orders. The original scenes are then archived into the Landsat Pathfinder Archive (LPA) under a project code which uniquely identifies the scenes as NALC Pathfinder data.

In parallel with the ordering of scenes, the geographic corner points for the selected scenes are used with EDC database software to identify the topographic map sheets corresponding to the respective scene path/rows. A subset of these maps is retrieved for use in ground control point selection for image-to-map registration. EDC has developed a relational database to facilitate archiving and retrieving all U.S. 1:24,000 scale quadrangle maps as well as the 1:250,000 and 1:50,000 maps received from Mexico's National Institute for Statistics, Geography, and Information (INEGI). This database will be augmented as maps are acquired for Central America and the Caribbean.

Triplicate Processing

The process of generating the triplicates involves a multi-stream approach (Figures 1 and 2). Ground control points are selected from the 1986 images and maps for use in developing the model for geometric transformation (geocoding). The map control points contain X and Y positional values and elevation values to correct for relief displacement. A cubic convolution registration is used to rectify and resample the image to a UTM projected output image. The image is comprised of 60 m x 60 m pixels, with an Root Mean Square Error (RMSE) of less than 1.0 pixel.

Concurrent with this activity, the 1970's scenes are radiometrically and geometrically pre-processed to convert the CCT-X data to a P-level product. The images are "destriped" to compensate for variations in the radiometric response of the individual detectors prior to geometric registration because the noise is scan-line dependent. An interim systematic correction is applied, using the satellite ephemeris data and platform navigation model, to generate a UTM projected output image that is oriented north-up.

Automated cross-correlation procedures are then implemented to extract control points from the 1970's and 1980's images to compute coefficients for image-to-image registration. This involves the use of a single band from each of the 1970's input images. Once an accurate transformation is developed, the grid for the interim systematic correction is convolved with the image-to-image transformation grid to produce coefficients that facilitate a single step registration of the 1970's P-product with the map registered 1980's image. The net result is an image registration procedure that only involves one step of resampling. The target RMSE for the image-to-image registration is 0.5 pixels or less. Previous studies have shown that the use of polynomial transformations alone on CCT-X format data yields only a 1.5-2.0 pixel internal image accuracy, once map projected. The use of a satellite model overcomes this problem and assists in meeting the registration criteria.

The last step involves creation of a pixel identity image to accompany each of the 1970's images. Each pixel value identifies the specific 1970's scene used to fill-out the WRS-2 path/row scene or "tile". This step is necessary due to the east-west shift in scene position from WRS-1 and WRS-2.

The procedures for the 1990's image registration are similar to those for the 1970's data, except that the 1990's data are acquired as P-level products. An interim systematic correction is applied, based on the satellite orbital data platform navigation model, to generate a north-up UTM projected image. Automated cross-correlation procedures are used to select control points, and a transformation grid is computed for the image-to-image registration. The two grids are convolved into a single grid which is then applied to the 1990's data to create an equivalent of the 1980's image. Similar to the 1970's processing effort, this action involves only one resampling step. The RMSE objective for this registration is 0.5 pixels or less.

Reduced Cloud Cover Composites (RCCC) are made after all data have been coregistered. This step is only performed in cases where 1990's scenes with 30% or less cloud cover are not available. To minimize the amount of cloud cover in the 1990's triplicate component, EDC has adapted AVHRR cloud-reduction compositing procedures for use in NALC triplicate generation. The compositing process operates on image pairs. The procedure is based on the Normalized Difference Vegetation Index (NDVI):

$$(\text{band } 4 - \text{band } 2)/(\text{band } 4 + \text{band } 2)$$

This index is sensitive to variations in surface characteristics, such as the presence or absence of green biomass, and other scene characteristics such as clouds. The NDVI is computed for each of the images to be used for compositing. The maximum NDVI value determines which input image pixel brightness values (BV) will be used to constitute the output image. This maximum NDVI decision rule is efficient for computing and yields consistent results as judged by comparisons of image and ground surface features. A 1990's triplicate component which has been composited will have two additional bands, a pixel identity image and the resulting RCCC or maximum NDVI composite image.

The final task in triplicate production involves making mosaics and a projection transformation of the Digital Elevation Model (DEM) data. The DEM data being used is derived from the DMA DTED data which were digitized from the standard NTMS 1:250,000 scale topographic maps, for which there is complete coverage for the United States and Mexico. These data, often referred to as the 3 arc-second DTED data, are made available as grid files corresponding to blocks in dimensions of 1° of latitude by 1° of longitude. These blocks are formed into a mosaic for the path/row of interest, and then re-projected and resampled to 60 m x 60 m pixels in UTM projection.

Image Rectification Analysis Forms

As explained previously, the image registration process will use ground control points or the ground control point library (GCPLIB) or "chips". The georegistration process will quantify the errors associated with the modelled transformation. An independent set of ground control points will be used to validate the accuracy of georegistration.

The following forms document the results of the registration of a NALC image. The forms will provide part of the documentation of quality and heritage of the image. These forms will be stored at the origin of production and may be accessed for quality assurance and quality control (QA/QC) requirements.

A sample of the Image Rectification Analysis Forms will be evaluated as part of the QA/QC efforts. It is anticipated that every tenth rectification will be evaluated by QA/QC personnel. Images or groups of images that fail the criteria will be re-processed. It is anticipated that the acceptance criteria for rectification will be + or - 1.0 pixel in comparison to ground position and + or - 0.5 pixel in image-to-image registration.

Figure 1.

Processing Flow for NALC Pathfinder Landsat MSS Triplicate Production

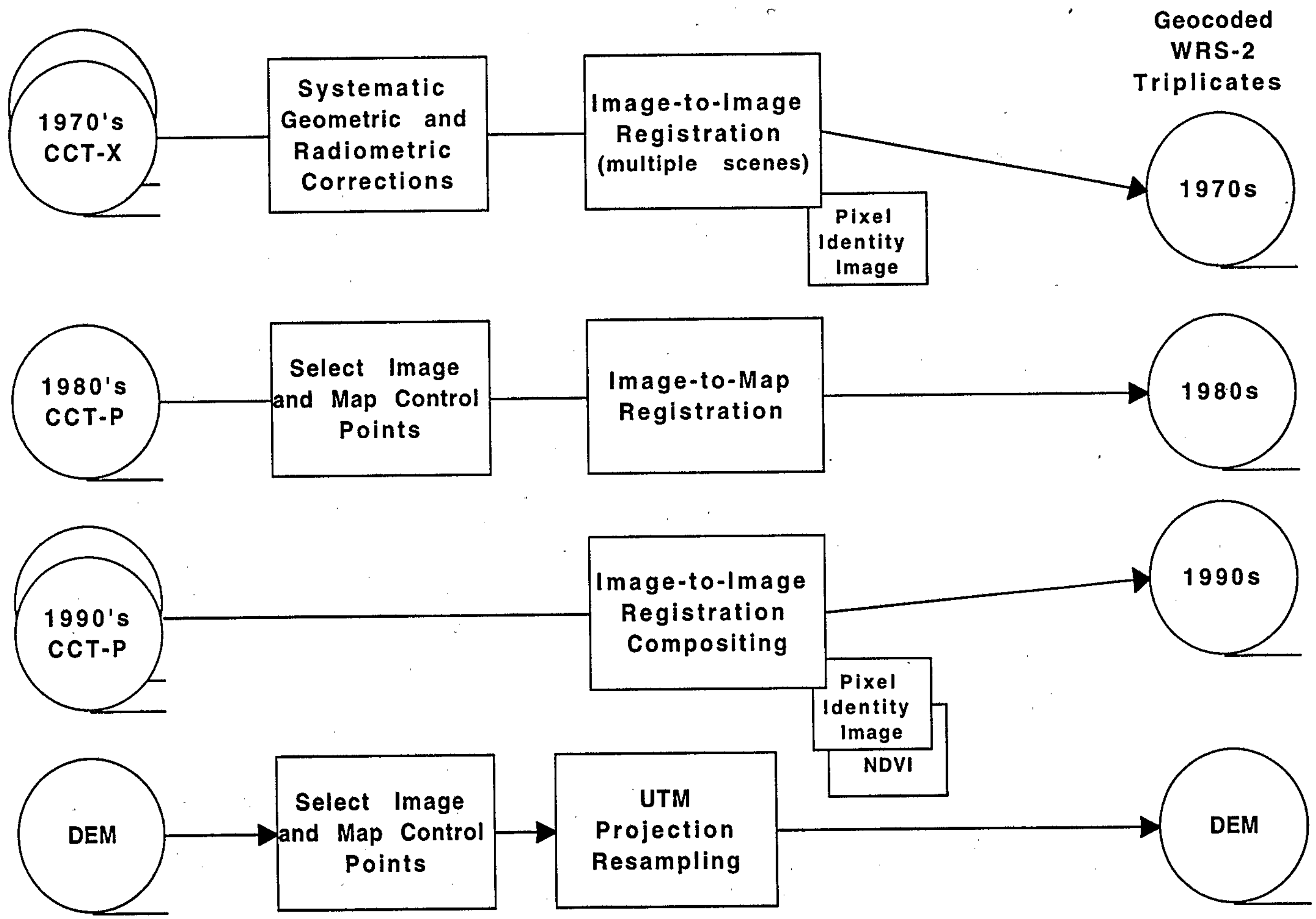

Figure 2.

NALC Pathfinder Data Flow

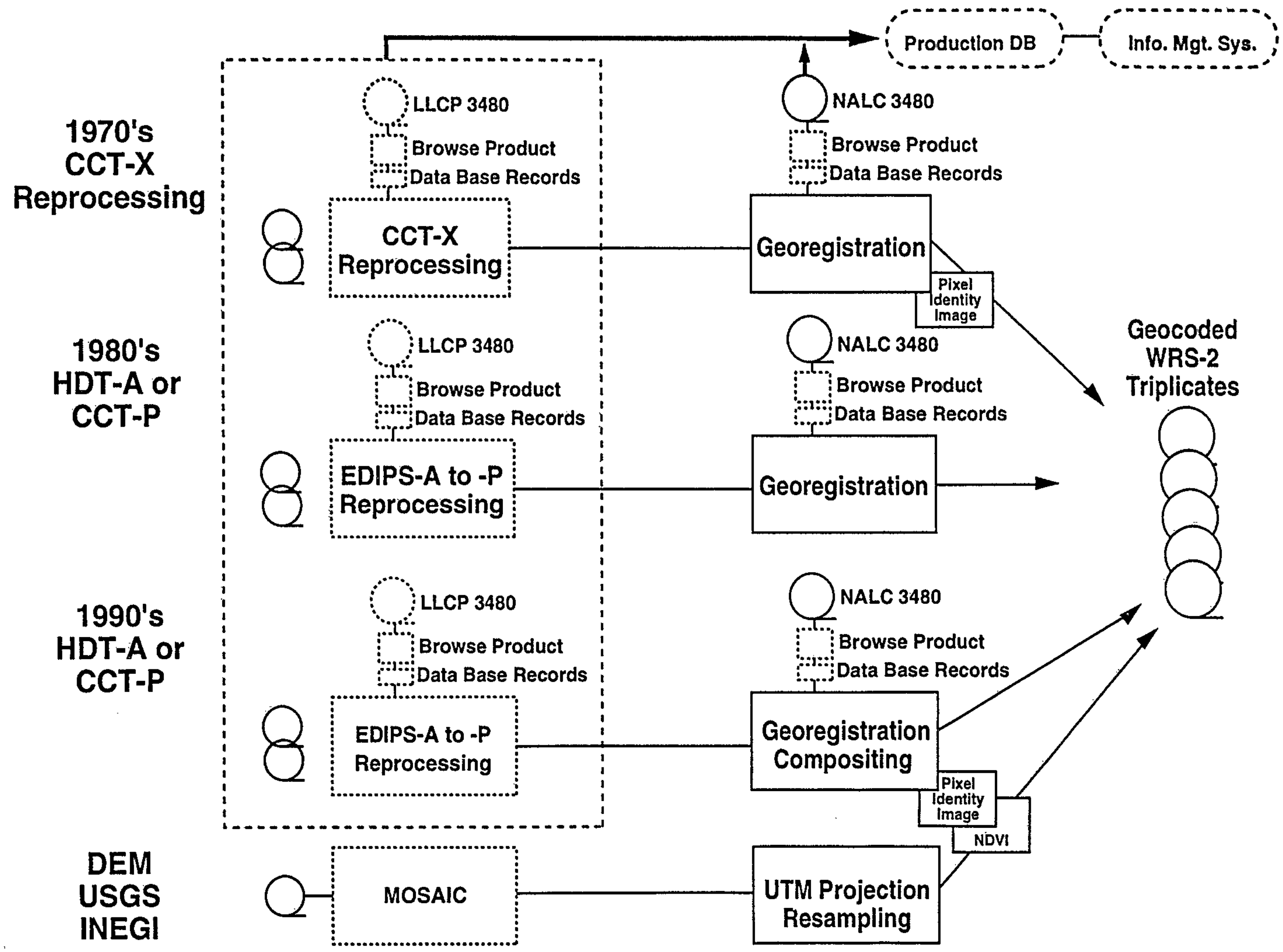

IMAGE RECTIFICATION ANALYSIS FORMS

The following forms record the characteristics of the image registration and rectification activities. These documents will be held at the point of origin.

```
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Input Tie Point Location File name:   [jones.nalc]8136615065500.match2;tpl
Output Tie Point Location File name:  [jones.nalc]test;tpl
Geometric Mapping Grid File name:     [jones.nalc]test;grid

Alpha (enter test):  0.050000
Alpha (exit test):   0.050000

Explanation of Active Flag Codes:
    0:  Accept manually extracted tie point
    1:  Accept automatically extracted tie point
    2:  Reject--correlation peak too near edge of search image
    3:  Reject--subsidiary peak comparable in strength to main peak
    4:  Reject--strength of peak below minimum specified by user
    5:  Reject--diagonal displacement from nominal location exceeds
                the maximum specified by the user
    6:  Correlation not attempted--error in correlation parameters
    7:  Reject--manually by the user
    8:  Reject--automatically by the modeling process
    9:  Reject--manually by the user during the modeling process
   1X:  Previously rejected point re-accepted manually by user
          X indicates original active flag code before re-acceptance
```

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INVERSE Transformation -- Coefficients map output to input space

Maximum permitted degree for approximation: 1

Coefficients:
F(X) = A(0) + A(1)X + A(2)Y

F(Y) = B(0) + B(1)X + B(2)Y

n	A(n)	B(n)	term
0	-9.421625460529e+00	6.938395968519e+00	Constant
1	1.009053869167e+00	-1.936929434901e-02	X
2	1.431734842178e-03	9.959803136471e-01	Y

Number of points used in fit: 21
Degrees of freedom in x: 18
Degrees of freedom in y: 18

Residual errors are given in pixels

Output Space Line	Output Space Sample	Lat/Y	Long/X	Elevation	Input Space Line	Input Space Sample	Residuals Line	Residuals Sample	Residual Magnitude	Code	Point Id
64.00	32.00	0.000	0.000	0.00	64.00	32.00	*** Not	Included	***	6	gpt1
64.00	64.00	0.000	0.000	0.00	64.00	64.00	*** Not	Included	***	2	gpt2
64.00	96.00	0.000	0.000	0.00	64.00	96.00	*** Not	Included	***	2	gpt3
64.00	128.00	0.000	0.000	0.00	64.00	128.00	*** Not	Included	***	2	gpt4
64.00	160.00	0.000	0.000	0.00	64.00	160.00	*** Not	Included	***	2	gpt5
64.00	192.00	0.000	0.000	0.00	64.00	192.00	*** Not	Included	***	2	gpt6
64.00	224.00	0.000	0.000	0.00	64.00	224.00	*** Not	Included	***	2	gpt7
64.00	256.00	0.000	0.000	0.00	64.00	256.00	*** Not	Included	***	2	gpt8
64.00	288.00	0.000	0.000	0.00	64.00	288.00	*** Not	Included	***	2	gpt9
64.00	320.00	0.000	0.000	0.00	69.21	327.27	*** Not	Included	***	8	gpt10
64.00	352.00	0.000	0.000	0.00	64.00	352.00	*** Not	Included	***	4	gpt11
64.00	384.00	0.000	0.000	0.00	61.61	378.06	-1.634	-0.088	1.636	1	gpt12
64.00	416.00	0.000	0.000	0.00	64.00	416.00	*** Not	Included	***	5	gpt13
64.00	448.00	0.000	0.000	0.00	64.00	448.00	*** Not	Included	***	2	gpt14
64.00	480.00	0.000	0.000	0.00	64.00	480.00	*** Not	Included	***	2	gpt15
64.00	512.00	0.000	0.000	0.00	64.00	512.00	*** Not	Included	***	6	gpt16
128.00	32.00	0.000	0.000	0.00	128.00	32.00	*** Not	Included	***	6	gpt17
128.00	64.00	0.000	0.000	0.00	128.00	64.00	*** Not	Included	***	2	gpt18
128.00	96.00	0.000	0.000	0.00	128.00	96.00	*** Not	Included	***	2	gpt19
128.00	128.00	0.000	0.000	0.00	128.00	128.00	*** Not	Included	***	2	gpt20
128.00	160.00	0.000	0.000	0.00	128.00	160.00	*** Not	Included	***	2	gpt21
128.00	192.00	0.000	0.000	0.00	128.00	192.00	*** Not	Included	***	2	gpt22
128.00	224.00	0.000	0.000	0.00	128.00	224.00	*** Not	Included	***	2	gpt23
128.00	256.00	0.000	0.000	0.00	128.00	256.00	*** Not	Included	***	2	gpt24
128.00	288.00	0.000	0.000	0.00	128.00	288.00	*** Not	Included	***	3	gpt25
128.00	320.00	0.000	0.000	0.00	128.26	313.92	0.033	0.262	0.264	1	gpt26
128.00	352.00	0.000	0.000	0.00	128.38	345.81	0.773	-0.136	0.785	1	gpt27
128.00	384.00	0.000	0.000	0.00	128.05	378.26	1.065	0.025	1.065	1	gpt28
128.00	416.00	0.000	0.000	0.00	128.00	416.00	*** Not	Included	***	4	gpt29
128.00	448.00	0.000	0.000	0.00	128.00	448.00	*** Not	Included	***	3	gpt30

128.00	480.00	0.000	0.000	0.00	128.00	480.00	*** Not Included ***			4	gpt31
128.00	512.00	0.000	0.000	0.00	128.00	512.00	*** Not Included ***			6	gpt32
192.00	32.00	0.000	0.000	0.00	192.00	32.00	*** Not Included ***			6	gpt33
192.00	64.00	0.000	0.000	0.00	192.00	64.00	*** Not Included ***			2	gpt34
192.00	96.00	0.000	0.000	0.00	192.00	96.00	*** Not Included ***			2	gpt35
192.00	128.00	0.000	0.000	0.00	192.00	128.00	*** Not Included ***			2	gpt36
192.00	160.00	0.000	0.000	0.00	192.00	160.00	*** Not Included ***			2	gpt37
192.00	192.00	0.000	0.000	0.00	192.00	192.00	*** Not Included ***			2	gpt38
192.00	224.00	0.000	0.000	0.00	192.00	224.00	*** Not Included ***			2	gpt39
192.00	256.00	0.000	0.000	0.00	192.00	256.00	*** Not Included ***			2	gpt40
192.00	288.00	0.000	0.000	0.00	192.36	281.70	-0.228	0.238	0.329	1	gpt41
192.00	320.00	0.000	0.000	0.00	192.22	313.81	0.248	0.061	0.255	1	gpt42
192.00	352.00	0.000	0.000	0.00	192.00	352.00	*** Not Included ***			4	gpt43
192.00	384.00	0.000	0.000	0.00	190.38	378.49	-0.349	0.156	0.382	1	gpt44
192.00	416.00	0.000	0.000	0.00	189.98	410.75	-0.133	0.126	0.183	1	gpt45
192.00	448.00	0.000	0.000	0.00	190.01	442.61	0.524	-0.304	0.606	1	gpt46
192.00	480.00	0.000	0.000	0.00	192.00	480.00	*** Not Included ***			2	gpt47
192.00	512.00	0.000	0.000	0.00	192.00	512.00	*** Not Included ***			6	gpt48
256.00	32.00	0.000	0.000	0.00	256.00	32.00	*** Not Included ***			6	gpt49
256.00	64.00	0.000	0.000	0.00	256.00	64.00	*** Not Included ***			2	gpt50
256.00	96.00	0.000	0.000	0.00	256.00	96.00	*** Not Included ***			2	gpt51
256.00	128.00	0.000	0.000	0.00	256.00	128.00	*** Not Included ***			2	gpt52
256.00	160.00	0.000	0.000	0.00	256.00	160.00	*** Not Included ***			2	gpt53
256.00	192.00	0.000	0.000	0.00	256.00	192.00	*** Not Included ***			2	gpt54
256.00	224.00	0.000	0.000	0.00	256.00	224.00	*** Not Included ***			2	gpt55
256.00	256.00	0.000	0.000	0.00	256.00	256.00	*** Not Included ***			3	gpt56
256.00	288.00	0.000	0.000	0.00	255.96	281.50	-0.372	-0.056	0.376	1	gpt57
256.00	320.00	0.000	0.000	0.00	256.77	313.01	1.058	-0.832	1.346	1	gpt58
256.00	352.00	0.000	0.000	0.00	256.00	352.00	*** Not Included ***			4	gpt59
256.00	384.00	0.000	0.000	0.00	256.00	384.00	*** Not Included ***			3	gpt60
256.00	416.00	0.000	0.000	0.00	253.66	410.90	-0.196	0.193	0.275	1	gpt61
256.00	448.00	0.000	0.000	0.00	253.20	443.16	-0.036	0.155	0.159	1	gpt62
256.00	480.00	0.000	0.000	0.00	253.41	481.38	*** Not Included ***			8	gpt63
256.00	512.00	0.000	0.000	0.00	256.00	512.00	*** Not Included ***			6	gpt64
320.00	32.00	0.000	0.000	0.00	320.00	32.00	*** Not Included ***			6	gpt65
320.00	64.00	0.000	0.000	0.00	320.00	64.00	*** Not Included ***			2	gpt66
320.00	96.00	0.000	0.000	0.00	320.00	96.00	*** Not Included ***			2	gpt67
320.00	128.00	0.000	0.000	0.00	320.00	128.00	*** Not Included ***			2	gpt68
320.00	160.00	0.000	0.000	0.00	320.00	160.00	*** Not Included ***			2	gpt69
320.00	192.00	0.000	0.000	0.00	320.00	192.00	*** Not Included ***			2	gpt70
320.00	224.00	0.000	0.000	0.00	320.00	224.00	*** Not Included ***			2	gpt71
320.00	256.00	0.000	0.000	0.00	320.00	256.00	*** Not Included ***			3	gpt72
320.00	288.00	0.000	0.000	0.00	320.00	281.49	-0.074	-0.153	0.170	1	gpt73
320.00	320.00	0.000	0.000	0.00	320.00	320.00	*** Not Included ***			3	gpt74
320.00	352.00	0.000	0.000	0.00	318.58	346.24	-0.254	0.020	0.255	1	gpt75
320.00	384.00	0.000	0.000	0.00	317.98	378.78	-0.239	0.271	0.361	1	gpt76
320.00	416.00	0.000	0.000	0.00	317.75	410.75	0.156	-0.052	0.164	1	gpt77
320.00	448.00	0.000	0.000	0.00	320.00	448.00	*** Not Included ***			3	gpt78
320.00	480.00	0.000	0.000	0.00	320.00	480.00	*** Not Included ***			2	gpt79
320.00	512.00	0.000	0.000	0.00	320.00	512.00	*** Not Included ***			6	gpt80
384.00	32.00	0.000	0.000	0.00	384.00	32.00	*** Not Included ***			6	gpt81
384.00	64.00	0.000	0.000	0.00	384.00	64.00	*** Not Included ***			2	gpt82
384.00	96.00	0.000	0.000	0.00	384.00	96.00	*** Not Included ***			2	gpt83
384.00	128.00	0.000	0.000	0.00	384.00	128.00	*** Not Included ***			2	gpt84
384.00	160.00	0.000	0.000	0.00	384.00	160.00	*** Not Included ***			2	gpt85

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384.00	192.00	0.000	0.000	0.00	384.00	192.00	*** Not Included ***			2	gpt86
384.00	224.00	0.000	0.000	0.00	384.00	224.00	*** Not Included ***			4	gpt87
384.00	256.00	0.000	0.000	0.00	384.00	256.00	*** Not Included ***			4	gpt88
384.00	288.00	0.000	0.000	0.00	383.67	282.08	-0.148	0.346	0.376	1	gpt89
384.00	320.00	0.000	0.000	0.00	384.00	320.00	*** Not Included ***			3	gpt90
384.00	352.00	0.000	0.000	0.00	382.73	346.31	0.149	-0.006	0.149	1	gpt91
384.00	384.00	0.000	0.000	0.00	381.54	378.37	-0.422	-0.237	0.484	1	gpt92
384.00	416.00	0.000	0.000	0.00	381.42	410.91	0.078	0.012	0.079	1	gpt93
384.00	448.00	0.000	0.000	0.00	384.00	448.00	*** Not Included ***			4	gpt94
384.00	480.00	0.000	0.000	0.00	384.00	480.00	*** Not Included ***			2	gpt95
384.00	512.00	0.000	0.000	0.00	384.00	512.00	*** Not Included ***			6	gpt96
448.00	32.00	0.000	0.000	0.00	448.00	32.00	*** Not Included ***			6	gpt97
448.00	64.00	0.000	0.000	0.00	448.00	64.00	*** Not Included ***			6	gpt98
448.00	96.00	0.000	0.000	0.00	448.00	96.00	*** Not Included ***			6	gpt99
448.00	128.00	0.000	0.000	0.00	448.00	128.00	*** Not Included ***			6	gpt100
448.00	160.00	0.000	0.000	0.00	448.00	160.00	*** Not Included ***			6	gpt101
448.00	192.00	0.000	0.000	0.00	448.00	192.00	*** Not Included ***			6	gpt102
448.00	224.00	0.000	0.000	0.00	448.00	224.00	*** Not Included ***			6	gpt103
448.00	256.00	0.000	0.000	0.00	448.00	256.00	*** Not Included ***			6	gpt104
448.00	288.00	0.000	0.000	0.00	448.00	288.00	*** Not Included ***			6	gpt105
448.00	320.00	0.000	0.000	0.00	448.00	320.00	*** Not Included ***			6	gpt106
448.00	352.00	0.000	0.000	0.00	448.00	352.00	*** Not Included ***			6	gpt107
448.00	384.00	0.000	0.000	0.00	448.00	384.00	*** Not Included ***			6	gpt108
448.00	416.00	0.000	0.000	0.00	448.00	416.00	*** Not Included ***			6	gpt109
448.00	448.00	0.000	0.000	0.00	448.00	448.00	*** Not Included ***			6	gpt110
448.00	480.00	0.000	0.000	0.00	448.00	480.00	*** Not Included ***			6	gpt111
448.00	512.00	0.000	0.000	0.00	448.00	512.00	*** Not Included ***			6	gpt112

Average Line Residual: 0.388957
Sample Residual: 0.177595
RMSE: 0.614462

Max Line Residual: -1.633832 Res Error: 1.636185 Point id: gpt12
Sample Residual: -0.832470 Res Error: 1.346371 Point id: gpt58

Geometric Mapping Grid file created with 43 rows by 10 columns
Number of output lines: 3724
Number of output samples: 4149

Average Grid Interpolation Line Residual: 0.000000
Sample Residual: 0.000000
RMSE: 0.000000

Max Grid Interpolation Line Residual: 0.000000
Sample Residual: 0.000000

Input verification file: [jones.nalc]8136615065500.verify1;tpl

Output image pixel size in meters: 60.00

Pt Id	Reference Image Line	Reference Image Sample	Registered Image Line	Registered Image Sample	Errors (meters) Line	Errors (meters) Sample	Errors (meters) Total
gpt85	768.0	2688.0	769.7	2687.1	-100.99	54.66	114.83
gpt87	768.0	2944.0	770.1	2943.0	-123.88	59.53	137.44
gpt116	1024.0	2560.0	1023.7	2558.0	20.05	122.63	124.26
gpt117	1024.0	2688.0	1024.5	2688.0	-31.47	-0.30	31.47
gpt118	1024.0	2816.0	1025.0	2815.8	-61.00	12.15	62.19
gpt121	1024.0	3200.0	1025.1	3199.0	-65.94	61.31	90.04
gpt148	1280.0	2560.0	1279.5	2559.6	27.63	23.93	36.55
gpt149	1280.0	2688.0	1279.9	2688.2	7.22	-13.53	15.33
gpt152	1280.0	3072.0	1279.9	3071.9	5.24	4.78	7.09
gpt155	1280.0	3456.0	1280.9	3455.0	-55.43	60.56	82.09
gpt179	1536.0	2432.0	1535.2	2432.6	51.00	-33.15	60.83
gpt183	1536.0	2944.0	1535.1	2944.0	51.70	1.01	51.71
gpt184	1536.0	3072.0	1534.7	3071.8	80.40	11.35	81.20
gpt186	1536.0	3328.0	1535.9	3327.8	6.62	13.22	14.78
gpt187	1536.0	3456.0	1536.2	3456.0	-13.60	2.01	13.75
gpt189	1536.0	3712.0	1537.1	3712.1	-63.37	-4.19	63.50
gpt212	1792.0	2560.0	1791.2	2560.3	48.82	-18.40	52.17
gpt213	1792.0	2688.0	1790.9	2688.8	66.39	-49.53	82.83
gpt217	1792.0	3200.0	1791.4	3199.9	33.99	3.16	34.13
gpt246	2048.0	2816.0	2047.4	2816.1	34.33	-4.19	34.59
gpt247	2048.0	2944.0	2046.7	2944.4	75.02	-25.18	79.14
gpt249	2048.0	3200.0	2047.1	3199.8	54.40	11.45	55.59
gpt278	2304.0	2816.0	2303.2	2816.3	45.37	-17.49	48.63
gpt281	2304.0	3200.0	2303.5	3199.9	31.90	6.21	32.49
gpt310	2560.0	2816.0	2559.7	2815.9	19.28	8.64	21.13
gpt312	2560.0	3072.0	2559.3	3071.8	40.58	14.35	43.04
gpt313	2560.0	3200.0	2559.7	3200.2	18.72	-9.49	20.98
gpt341	2816.0	2688.0	2815.8	2688.5	11.65	-30.63	32.77
gpt343	2816.0	2944.0	2816.1	2944.0	-4.66	0.39	4.67
gpt369	3072.0	2176.0	3073.0	2176.0	-62.54	2.43	62.58
gpt370	3072.0	2304.0	3073.9	2304.9	-116.58	-56.01	129.34
gpt374	3072.0	2816.0	3072.4	2816.3	-23.52	-19.59	30.61
gpt375	3072.0	2944.0	3072.5	2943.8	-28.57	11.80	30.91
gpt376	3072.0	3072.0	3072.8	3072.0	-50.48	2.28	50.53

Line error average = -2.109667 meters RMSE = 54.134153 meters
Sample error average = 6.063383 meters RMSE = 34.409301 meters
RMSE of total error = 64.144419 meters
RMSE of total error in pixels = 1.069074

IMAGE CATEGORIZATION AND DEVELOPMENT

OF LAND COVER DATA PRODUCTS

Training Set Development

The development of training sets for categorization requires a method that will yield high quality and unbiased training set characteristics in an automated fashion. The unsupervised training set development approach has been proven successful in providing good, homogeneous spectral clusters in applications such as land cover or landscape characterization. The unsupervised approach negates many systematic problems associated with atmospheric and terrain radiometric distortions. This approach has been used successfully for over twenty years, and it can also be implemented with a minimum of effort. Consistent results can be expected for most applications.

Unsupervised training set development will be conducted with an automated spectral clustering algorithm. A common clustering method has been selected from available choices in the literature of remote sensing applications and has been developed into an algorithm by EMSL-LV personnel.

Training set development will be conducted with some assumptions and input parameters. Individual scenes of the triplicate will be clustered separately. Each scene will be clustered on an iterative basis for as many as one-hundred or more clusters or classes. Criteria for linking or breaking of clusters will be established empirically.

Several approaches to unsupervised training set development will be tested. These include clustering using an EMSL-LV procedure and using procedures employed by the commercially available image processing software currently in place at the EMSL. These procedures will be tested as part of the standard methods development activities that form the Chesapeake Bay Watershed and State of Chiapas, Mexico Pilot Studies.

Evaluation of Training Sets

The results of unsupervised training set development will be evaluated in several manners. A preliminary categorization image will be produced from the unsupervised training set development or clustering activity. This image will help indicate the location of many clusters or classes.

The preliminary categorized image will be used along with other procedures to evaluate the quality of individual training sets or clusters using aerial photo or other data. Procedures will include divergence calculations, bi-variate scatter plots of cluster means and variance-covariance, and comparison of the preliminary categorized image with ground information or aerial photographs.

Following analyses of the quality of training sets, the contents may be edited to remove examples of poor clusters, e.g., clusters that represent very few pixels in the original image, overlapping clusters, and clusters that are composed of more than one distinct, spectrally homogeneous land cover class.

Categorization

The edited training sets will be used for categorization of all three original scenes from the triplicate. The maximum likelihood / Bayes decision rule approach to categorization will be evaluated. There are a number of reasons to use this approach, among which is the fact that it has been successfully used in remote sensing applications for over twenty years. This approach makes use of both Euclidean distance measurement and probability-based criteria in the determination of the class identity of a given pixel. The use of these criteria makes the categorizing algorithm more sensitive to class characteristics as compared to single-criterion approaches.

After evaluation of training set quality, the scene from the triplicate will be categorized using all four bands as input to the maximum likelihood classification algorithm. The work will be completed at EMSL-LV and will employ the scene triplicates produced by EDC.

The resulting product of one hundred or more classes will represent a Preliminary Land Cover (PLC) product. It remains to identify the land cover type of each cluster or class. This activity is known as "labelling" and will be perform by using local knowledge, ground information, aerial photographs and maps. The PLC product will require that certain clusters or classes be aggregated or "lumped" to render the best product. This aggregation will allow inventory of several clusters or classes that may represent the same functional land cover class as represented in the NALC land cover categorization system.

Identification of Land Cover and Classification System

The land cover classes in the PLC image will be labelled as to cover type using a land cover classification system. The NALC classification system was developed to specifically support NALC project objectives and to be compatible with the other major land cover classification systems. The NALC classification system is compatible with the Anderson et al. (1976), Cowardin et al. (1979) and Brown et al. (1979) systems. The system has been optimized to support carbon inventory applications.

The standard NALC characterization data base products will be based on Level 2 classes (Figure 3). For a more complete description of the NALC system and definitions of land cover types, refer to Appendix X.

The assignment of class types to PLC classes will be performed by NALC cooperators. The scheme is presented below, with Level 2 as the final land cover type detail to be identified. This approach will supply sufficient detail while using the capabilities of MSS data to their best measure. It is recognized that differentiation between forest and shrub/scrub classes at Level 2 will be difficult and in some cases not possible without the aid of ancillary data. However, a best effort will be made throughout North America to accomplish this differentiation.

The resulting product will be the Land Cover thematic data coverage products (LC) for each path / row. It will be supplied to EMSL-LV for validation. Subsequent to data validation, LC products will be archived at EMSL-LV. After validation, the products will be archived and distributed by EDC. The image will be accompanied by details on the training sets including cluster or class means in each band, variance-covariance matrix, class identities, and details related to quality and accuracy.

Data Production and Distribution

The data are to be processed by three groups, USGS-EDC, EPA EMSL-LV, and the cooperators. The triplicates produced by EDC will be distributed initially to EMSL-LV. EMSL-LV will conduct image pre-processing, training set selection, training set evaluation, and maximum likelihood categorization. EMSL-LV will distribute NALC triplicate scenes, the categorized or clustered image scenes (Preliminary Land Cover, PLC), as well as documents on standard processing methods to the cooperators. Cooperators will identify the clusters or classes of the PLC maps, aggregate and assign land cover types from the categorization system, and create the Land Cover (LC) products. The cooperators will supply the LC products to EMSL-LV for archive. The LC products will be tested against standards and for quality (data validation), and then sent to EDC for archive and distribution to users.

Quality and Accuracy Assessment

The evaluation of data quality has been addressed in two manners: the systematic sources of errors in production; and the accuracy of derived products. Once the systematic or within-system evaluations have been performed and the characteristics of the triplicates and derived products determined to meet the standards, the data characteristics will be recorded and stored at the point of origin (EDC).

The accuracy of derived products, such as the Land Cover products, will be tested. The results will be stored as an attribute file and maintained at the point of origin. Accuracy of each land cover class, the error matrix, and other details will be included.

The accuracy assessment information of the LC data sets must pass validation. EMSL-LV personnel will take the data and develop the accuracy assessment calculations and results. The criteria are described in the section on QA/QC.

The LC data sets will be re-evaluated if they fail the above criteria. The evaluation will focus on determining whether the initial classes were incorrectly aggregated, were incorrectly labelled, or were subject to other sources of errors. If the source of error can be identified and a correction can be made, the image will enter the stream for further evaluation. If it fails again, a new attempt will be made at categorization, and results will be evaluated for accuracy until a solution of the problem is identified and the criteria are met.

NALC Products

Products provided by the NALC project will include post-processed remote sensor data, post-processed digital elevation model data (DEM), intermediate categorization products, and final database categorization products. All NALC products will be "clipped" to the World Reference System 2 (WRS 2) path/row scene configuration.

NALC standard data products will include the following: triplicate data sets georeferenced and coregistered Landsat MSS imagery (1991, 1986, 1973 plus or minus one year); spectral clustered categorized images for each Landsat MSS image; and coregistered DEM data. Categorization database products will include complete (100%) image categorizations for Landsat MSS scenes from 1991 plus or minus one year, and partial image categorization products for Landsat MSS scenes from 1986 and 1973 plus or minus one year. For the Landsat MSS 1986 and 1973 scenes, only the areas that have undergone significant levels of spectral change will be available in categorized form.

Anderson, J., Hardy, E., Roach, J., and Witmer, R., 1976, A Land Use Classification System for Use With Remote-Sensor Data, U.S. Department of the Interior, U.S. Geological Survey Professional Paper 964, Washington, DC, 28 pp.

Brown, D., Lowe, C., and Pase, C., 1979, A Digitized Classification System for the Biotic Communities of North America, With Community (Series) and Association Examples for the Southwest, Journal of the Arizona-Nevada Academy of Science 14:1-16.

Cowardin, L., Carter, V., Golet, F., and LaRoe, E., 1979, Classification of Wetlands and Deepwater Habitats of the United States, U.S. Department of Interior, U.S. Fish and Wildlife Service, Rep. No. FWS/OBS-79/31, Washington, DC, 103 pp.

Figure 3.

NALC Pathfinder Categorization System

LEVEL 0	LEVEL 1	LEVEL 2
Land	1.0 Barren or Developed Land	1.1 Exposed Land
		1.2 Developed Land
	2.0 Woody	2.1 Forest
		2.2 Scrub/Shrub
	3.0 Herbaceous	3.1 Herbaceous
	4.0 Arid	4.1 Arid Vegetation
		4.2 Riparian
	5.0 Snow/Ice	5.1 Snow/Ice
Water	6.0 Water & Submerged Land	6.1 Ocean
		6.2 Coastal
		6.3 Near-Shore
		6.4 Inland
Other	7.0 Other	7.1 Cloud
		7.2 Shadow
		7.3 Missing
		7.4 Indeterminable

METHODS FOR MANAGING AND DISTRIBUTING

NALC DATA AND PRODUCTS

The NALC-Pathfinder products will be identified, indexed and archived. The NALC product characteristics will be stored in an Information Management System (IMS) or "meta" data set housed at EROS Data Center (EDC). This will allow identification and tracking of NALC products even when archive products are stored at different physical locations.

These new products require new identification numbers to be assigned. This is due to the variety of Pathfinder products that will be stored in the archive and the variety of data characteristics. The Information Management System (IMS) will require additional fields of meta data beyond the fields specified in existing systems (Figure 4).

The population of image scenes in the archive will include derivative products created outside of the EDC environment. These products need to be produced with NALC standard processing procedures. They must be of known and documented quality as per NALC standard quality characteristics. To be included in the archive, products must be uniform and adhere to NALC standards.

NALC Data Archive, Management, and Distribution

EDC has responsibility for the archive, management, and distribution of NALC Pathfinder products (original Landsat MSS CCTs, geocoded triplicates, DEMs, and derivative products). EDC also has this responsibility for other Landsat Pathfinder projects. Consequently, a long-term strategy for data archive, management, and distribution must address project-specific needs in the context of the overall Landsat Pathfinder Program goals.

Towards this end, an interim Information Management System (IMS) approach is being developed to facilitate the indexing, archiving, and distribution of NALC data sets. This approach is designed to develop a database that is populated by metadata which describe NALC data sets. It is also important that this IMS be upwardly compatible with the Version 0 IMS at the Land Processes Distributed Active Archive Center (LPDAAC) for EOSDIS.

The Version 0 IMS at the LPDAAC will ultimately be used to manage all Landsat Pathfinder Project data (source data and derivative products). This IMS will be separate from the current Global Land Information System (GLIS), which currently facilitates query, browse, and product ordering from the National Satellite Land Remote Sensing Data Archive (NLSRSDA). GLIS is linked to the NSLRSDA production database and is not currently structured to handle higher level data products, such as those being generated by NALC.

The types of metadata being compiled and tracked along with the triplicate data sets are listed in Table 2 and described in Table 3. These particular attributes are considered essential for describing the NALC triplicate components. The higher level data products which will be produced later (cluster data sets, land cover products, etc.) can be expected to have different or expanded metadata requirements. Currently, this metadata is managed using a relational database management system (RDBMS), specifically D-Base IV. However, in response to the Peer Review Panel Meeting in New Orleans, EDC has investigated the IMS developed by the University of New Hampshire for the Humid Tropical Forests Inventory Project (HTFIP), which is another Landsat Pathfinder activity. The HTFIP IMS is based on ARC/INFO capabilities, and provides graphic displays of data coverage, browse images of selected scenes, and the ability to query some metadata attributes.

Upon evaluation of the HTFIP IMS, EDC has concluded this capability can be developed for NALC in a more efficient manner using ARC VIEW capabilities. The D-Base IV information which has been compiled would be upwardly compatible, so no effort to date has been wasted. The following elements are functional capabilities which an IMS should support: Graphical display of the extent of data coverage; geographic query; interrogation of metadata attributes; data richness or status tracking; viewing of selected browse products; linkages between NALC triplicates and their source in GLIS; and the ability to execute product orders.

The interim IMS is not likely to provide immediately open access to the general public, but it should serve the internal needs of EDC for product development and tracking and be portable to EMSL-LV. EDC will provide EMSL with regular, periodic updates to the metadata. In addition to providing support to NALC production and data management activities, the interim IMS will aid in defining the functional requirements of the Version 0 IMS. EDC staff are currently investigating IMS requirements for the Landsat Pathfinder projects as part of a larger effort to assess the resources required to upgrade GLIS as a phased approach to the LPDAAC Version 0 IMS development.

NALC Data Distribution

EDC is currently distributing the NALC triplicate products to EMSL on 8mm Exabyte cartridges. These tapes contain the data description record (DDR) files in ASCII format, and the image data in band-sequential format (Table 4).

The DDRs (Table 5) contain information describing the image projection parameters and UTM coordinates. The order in which files are written to tape (Table 6) is always the same, except the number of files depends on the number of scenes used for each of the 1970's and 1990's components.

The image files, in turn, vary in size (i.e., number of bands) depending on the requirements for cloud composite and mosaic products. A DDR file is written before each image file, and the geographic coordinates are always based on the 1986 scene which was map-registered. All files (images and DEM) have the same dimensions (NL, NS); the MSS images are 8-bit (BYTE) data, whereas the DEM is 16-bit (INTEGER*2).

Query Procedures

The information on NALC-Pathfinder products in the Information Management System will be available for a number of characteristics. The details on a given image may be queried from fields set up to index NALC-triplicate and derivation image product characteristics.

Users would enter the IMS via communication link from a workstation. The query sequence can be called up and executed, and the user could examine the fields by individual scene. The fields could also be used to search the database for a given set of criteria. Searches by location, date, cloud cover, and so on could be searched to identify scenes of interest.

These and other data fields (Tables 2 and 3) are still to be evaluated. It may be desirable to add or subtract field types from the list above to optimize the information content while minimizing redundant, unnecessary, or costly information fields.

Product Media Available to the User

The NALC-Pathfinder products will be available from EDC. Products will be sold at the cost of duplication. The media for distribution will include a number of types. This is due to the variety of hardware owned by users and due to the fact that media types change over time. NALC products such as scene triplicates will be available on nine track tape, on 8mm tape, and on 3480 type magnetic tape cartridges.

The media type mix may change over the life of the program. This could be caused by a change in industry standards for media or media hardware. It could also be caused by a change in user selection of storage devices or by experience with media that does not meet the requirements of the project.

EDC archives the NALC image data on 3480 cartridge media and only uses the 8mm cartridges for distribution to EMSL. EDC recommends that users verify all 8mm cartridges upon delivery and that the data be backed-up on 9-track tapes or other media. The Exabytes may not be reliable long-term storage media. On several occasions EMSL has not been able to read the 8mm cartridges, even though EDC has been able to successfully run tape mappers on them prior to shipping. In addition, there have been a number of calls from other users who have been unable to read these tapes.

Standard Product Ordering Procedures

Data orders from the archive will be accomplished by standard ordering procedures at EROS Data Center. Orders are currently made by correspondence, or through electronic ordering procedures available through the EDC's IMS or GLIS query systems.

Alternative Products and Ordering Procedures

Cooperators will receive data from EMSL-LV, and return project related products to EMSL-LV. Cooperators with EPA may obtain data from EMSL-LV.

Figure 4.

Landsat Pathfinder (LP) Program Data Management Concept

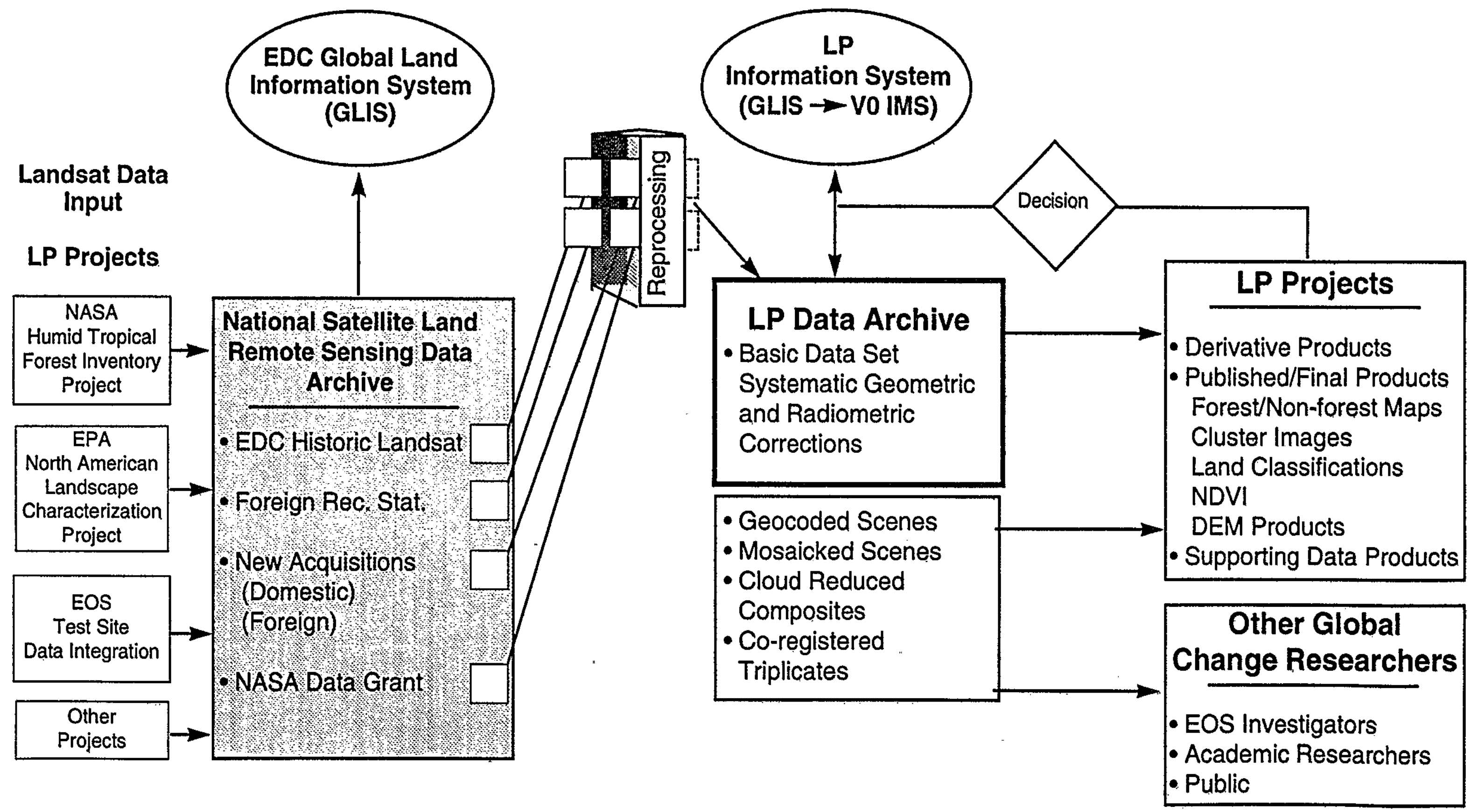

Table 2.

Interim NALC IMS Metadata Database Schema

Structure for database: C:\PATHFIND\NALC\NALC.DBF
Number of data records: 4
Date of last update : 04/22/93

Field	Field Name	Type	Width	Dec	Index	Example
1	TAPEID	Character	6		N	31051
2	LEVEL	Character	1		N	G
3	PATH	Numeric	3		N	16
4	ROW	Numeric	3		N	31
5	DECADE	Numeric	2		N	70
6	ENTERDT	Date	8		N	04/22/93
7	PROJCODE	Character	1		N	U
8	FORMAT	Character	4		N	CCTX
9	RESAMP	Character	1		N	C
10	SCENE1	Character	16		N	8104515240500
11	CTLPTS1	Numeric	4		N	97
12	RMSERR1	Float	4	2	N	0.65
13	ACQDATE1	Date	8		N	09/06/72
14	SUNELEV1	Numeric	2		N	47
15	SUNAZIMUT1	Numeric	3		N	139
16	SCENE2	Character	16		N	
17	CTLPTS2	Numeric	4		N	0
18	RMSERR2	Float	4	2	N	0.00
19	ACQDATE2	Date	8		N	00/00/00
20	SUNELEV2	Numeric	2		N	0
21	SUNAZIMUT2	Numeric	3		N	0
22	SCENE3	Character	16		N	
23	CTLPTS3	Numeric	4		N	0
24	RMSERR3	Float	4	2	N	0.00
25	ACQDATE3	Date	8		N	00/00/00
26	SUNELEV3	Numeric	2		N	0
27	SUNAZIMUT3	Numeric	3		N	0
28	SCENE4	Character	16		N	
29	CTLPTS4	Numeric	4		N	0
30	RMSERR4	Float	4	2	N	0.00
31	ACQDATE4	Date	8		N	00/00/00
32	SUNELEV4	Numeric	2		N	0
33	SUNAZIMUT4	Numeric	3		N	0
34	SOURCE	Character	16		N	I2I
35	CONTACT	Character	30		N	TBD
36	PHONE	Character	14		N	TBD
** Total **			238			

Table 3.

Definitions for NALC Interim IMS Database Schema

Field Definitions:

TAPE ID = EDC archive storage location, the tape id serves as a unique reference
identity combined with the path, row and decade fields.
Valid formats are:
 A#### - 1 space, 1 alpha character and 4 numbers.
 AA#### - 2 like alpha characters and 4 numbers.
 ###### - 6 numbers.

LEVEL = level of processing performed.
Valid codes are:
 P - processed, G - geocoded/georegistered, M-mosaic,
 C - composite, E - DEM.

PATH = a World Wide Reference System defined nominal Landsat satellite track
(path). All processed NALC data is referenced to WRS2.
Valid values are:
 1 - 233

ROW = a World Wide Reference System defined nominal latitudinal center line
of a Landsat image. The row indicator represents scene centers that
are chosen at 25-second (LS 1-3) and 23.92-second (LS4/5) increments
along the orbital track in either direction of the equator.
Valid values are:
 1 - 59 = Northern Hemisphere (Descending)
 60 = Equator (Descending)
 61 - 119 = Southern Hemisphere (Descending)
 120 - 122 = Southern Polar Zone (Descending)
 123 - 183 = Southern Hemisphere (Ascending)
 184 = Equator (Ascending)
 185 - 246 = Northern Hemisphere (Ascending)
 247 - 248 = Northern Polar Zone (Ascending)

DECADE = acquisition decade of set.
Valid codes are:
 70 - 1970's.
 80 - 1980's.
 90 - 1990's.

ENTERDT = the date the metadata record is added to the data base.

PROJCODE= map projection, default is 'U'.
Valid codes are:
U - UTM or Universal Transverse Mercator.
S - SOM or Space Oblique Mercator.
H - Hotine.

FORMAT = data's current input format.
Valid codes are:
CCTX - EDC computer compatible tape in X format.
EDIP - EDC Enhanced Digital Image Processing System's format.
DEM - EDC digital elevation model format.
FAST - EOSAT's fast format.

RESAMP = resampling technique used to radiometrically process the data.
Valid codes are:
C = cubic convolution.
N = nearest neighbor.
processing.
B = bilinear.

SCENE1 = a systematically corrected scene id or the first scene id used in generating a mosaic or composite.

SCENE2-4= 2 to 4 scene ids used to generate a mosaic or composite.

CTLPTS1 = total number of geographic control points used for scene 1.

CTLPTS2-4= total number of geographic control points used for each scene 2 - 4.

RMSERR1 = the average root-mean-square error made using each scene's control points (i.e. RMSERR1 applies directly to SCENE1 and CTRLPTS1 just as ...RMSERR2/3/4 applies directly to their respective SCENE/CTRLPT numbers).

RMSERR2-4= the average root-mean-square error made using each like numbered scene's control points.

ACQDATE1= the acquisition date applicable to the first scene id.

ACQDATE2-4= the acquisition date applicable to the like numbered scene id.

SUNELEV1 = the elevation angle of the sun above the horizon.
(Valid values = 0 to 90 degrees)

SUNELEV2-4=the sun elevation applicable to the like numbered scene id.

SUNAZIMUT1 = the azimuth angle of the sun measured clockwise from north in
degrees. (Valid values = 0 to 360 degrees)

SUNAZIMUT2-4=the sun azimuth applicable to the like numbered scene id.

SOURCE = base source used in registration.
Valid sources are:
24kUSGS = 1:24k USGS topo map.
50kMEXC = 1:50k Mexico topo map.
I2I = image to image registration.

CONTACT = a contact person available offsite whom fully knows the projects.
Valid contact is:
TBD

PHONE = contact person's office phone number.
Valid phone number is:
TBD

Table 4.

8mm Tape Mapper for NALC Triplicate

```
********** Mapper of tape cct mounted on DRIVE 4 **********
       1 RECORDS   3428 BYTES LONG
END OF FILE #1 >>>>> 1 TOTAL RECORDS.

   25000 RECORDS   5000 BYTES LONG
END OF FILE #2 >>>>> 25000 TOTAL RECORDS.

       1 RECORDS   3428 BYTES LONG
END OF FILE #3 >>>>> 1 TOTAL RECORDS.

   25000 RECORDS   5000 BYTES LONG
END OF FILE #4 >>>>> 25000 TOTAL RECORDS.

       1 RECORDS   3032 BYTES LONG
END OF FILE #5 >>>>> 1 TOTAL RECORDS.

   20000 RECORDS   5000 BYTES LONG
END OF FILE #6 >>>>> 20000 TOTAL RECORDS.

       1 RECORDS   3824 BYTES LONG
END OF FILE #7 >>>>> 1 TOTAL RECORDS.

   30000 RECORDS   5000 BYTES LONG
END OF FILE #8 >>>>> 30000 TOTAL RECORDS.

       1 RECORDS   1849 BYTES LONG
END OF FILE #9 >>>>> 1 TOTAL RECORDS.

    5000 RECORDS  10000 BYTES LONG
END OF FILE #10 >>>>> 5000 TOTAL RECORDS.

**********  END OF TAPE  **********
```

Table 5.

Example of Data Descriptor Record (DDR)

```
  IMAGE NAME:85068515574x0.trimp

          NL:5000          NS:5000          NB:4
DTYPE:BYTE
  LAST MODIFIED:          DATE:10-Feb-93    TIME:1643:01
SYSTEM:ieee-std
  PROJ. CODE:(1)UTM
Valid:VALID
   ZONE CODE:15
Valid:VALID
  DATUM CODE:0
Valid:VALID
  PROJ. PARM:
Valid:VALID
  A:    -1.61239334063410E+00    2.52200076913181E-01
9.99600000000000E-01
  B:     0.00000000000000E+00   -9.30000000000000E+07
0.00000000000000E+00
  C:     5.00000000000000E+05    0.00000000000000E+00
0.00000000000000E+00
  D:     0.00000000000000E+00    0.00000000000000E+00
0.00000000000000E+00
  E:     0.00000000000000E+00    0.00000000000000E+00
0.00000000000000E+00
 CORNER COOR:
Valid:VALID
    ULcorner:1.70538000000000E+06   4.44960000000000E+05
    URcorner:1.70538000000000E+06   7.44900000000000E+05
    LLcorner:1.40544000000000E+06   4.44960000000000E+05
    LRcorner:1.40544000000000E+06   7.44900000000000E+05
  PROJ. DIST:6.00000000000000E+01   6.00000000000000E+01
Valid:VALID
 PROJ. UNITS:METERS
Valid:VALID
   INCREMENT:1.00000000000000E+00   1.00000000000000E+00
Valid:VALID
 MASTER COOR:1       1
```

IMAGE NAME:85068515574x0.trimp

BAND NO:1

MINIMUM:0.0000000000000E+00
Valid:INVALID
MAXIMUM:0.0000000000000E+00
Valid:INVALID

DATA SOURCE:Landsat 5
SENSOR TYPE:MSS
CAPT. DIRECTION:descending

DATE:15-JAN-86
TIME:1557:4

IMAGE NAME:85068515574x0.trimp

BAND NO:2

MINIMUM:0.0000000000000E+00
Valid:INVALID
MAXIMUM:0.0000000000000E+00
Valid:INVALID

DATA SOURCE:Landsat 5
SENSOR TYPE:MSS
CAPT. DIRECTION:descending

DATE:15-JAN-86
TIME:1557:4

IMAGE NAME:85068515574x0.trimp

BAND NO:3

MINIMUM:0.0000000000000E+00
Valid:INVALID
MAXIMUM:0.0000000000000E+00
Valid:INVALID

DATA SOURCE:Landsat 5
SENSOR TYPE:MSS
CAPT. DIRECTION:descending

DATE:15-JAN-86
TIME:1557:4

IMAGE NAME:85068515574x0.trimp

BAND NO:4

MINIMUM:0.00000000000000E+00
Valid:INVALID
MAXIMUM:0.00000000000000E+00
Valid:INVALID

DATA SOURCE:Landsat 5
SENSOR TYPE:MSS
CAPT. DIRECTION:descending

DATE:15-JAN-86
TIME:1557:4

Table 6.

Explanation of NALC Tape Mapper

File #1: Data Descriptor Record (DDR) file which is based on the georeferencing parameters for the 1980's data image to map registration. The projection information is the same for the 1990s and 1970s data. This is an ASCII file.

File #2: image data for the first 1970s scene used in the triplicate. This contatins four bands of MSS and the pixel identity image. The pixel value used to identify this scene can be cross referenced to the Dbase records which will follow separately.

File #3: DDR for the next 1970s scene (if more than 2 are used)

File #4: the next 1970s scene; four MSS bands and a pixel identity image (as above)

File #5: DDR for the 1980s scene

File #6: 1980s image data; four MSS bands; no pixel identity image required

File #7: DDR for the 1990s data

File #8: the 1990s image data; four MSS bands, NDVI image resulting from cloud reduced compositing, and the pixel identity image. The last two bands only exist when compositing is done. Band 5 is the maximum NDVI image resulting from the multiple inputs. The pixel with the maximum NDVI value is used to determine which input pixel DN values are used to create the output. Bnad 6 is the pixel identity image. These pixel values are indexed to the scene from which the output pixel values were taken. The pixel values correspond to the scene number in the dBASE record (dBASE information isdistributed only to EPA-EMSL).

File #9: DDR for the DEM generated for that Path/Row. The projection parameters should match those of the MSS data.

File #10: DEM data for the triplicate; same dimensions as the MSS image data, except that it is INTEGER*2

IDENTIFICATION OF CHANGE DETECTION METHODS

Introduction

The goal of NALC change detection methods development research is to select or develop standard change detection methods for both pre- and post-categorization delineations of change in land covers. For the pre-categorization change detection technique, only those areas that have undergone significant spectral change will be categorized. The pre-categorization technique will be utilized as the preferred NALC change detection method. The post-categorization change detection technique will only be used when pre-categorization is not technically feasible. This method will be a raster-based Geographic Information System (GIS) operation and would require complete (100%) categorized digital database products for multiple dates. Because of the emphasis on carbon issues, the NALC-Pathfinder will place a special emphasis on detecting land cover changes involving forests, which hold more carbon per above-ground area than other major land cover types. NALC is interested in both the losses and gains in forest area plus the detection of forests which have been placed into a regrowth stage due to disturbance.

Change Detection Literature Review

Early efforts at using Landsat MSS data for the detection of land cover change were largely based on visual interpretation of the multitemporal images. This is essentially a photointerpretation process, using techniques developed in the decades preceding the launch of Landsat in 1972 (Shepard 1964). This method is still widely used for change detection. It is perhaps the most direct and fastest change detection technique, particularly in the initial stages of a change detection project.

Following the use of visual interpretation for change detection, digital methods began to be employed. Change detection methods have been broadly divided into either enhancement (pre-categorization) or post-categorization methods (Nelson 1983, Pilon et al. 1988, Singh 1989).

Enhancement change detection techniques involve the transformation of two original images to a new single-band or multi-band uncategorized image in which the areas of land cover change are readily detected. The change-enhanced data can be further processed by other analytic methods, such as by using a categorizer, to produce a labeled change detection output product. Most of the enhancement techniques are based on the concepts of image differencing or image ratioing (Weismiller et al. 1977, Toll et al. 1980). Differencing of vegetation indices has been a popular form of enhancement change detection (e.g., Nelson 1983). It has been shown that image equalization in the data pre-processing stage usually improves the results of change detection (Hall et al. 1991). Techniques like band-to-band regressions and principal components analysis have been used to simultaneously perform the image-to-image equalization and the detection of change areas (Ingram et al. 1981 and other references).

In post-categorization change detection two images from different dates are independently categorized. The area of change is then extracted through the direct comparison of the categorization results (e.g., Colwell and Weber 1981). The advantage of post categorization change detection is that it bypasses the difficulties in change detection associated with the analysis of images acquired at different times of year or by different sensors. The disadvantages of the post-categorization approach include greater computational and labeling requirements, high sensitivity to the individual categorization accuracies, plus the difficulties in performing adequate accuracy assessment on historic data sets.

The Landsat Pathfinder Humid Tropical Forest Inventory Project, being performed at the University of New Hampshire and the University of Maryland, uses a post-categorization change detection method. Because of the small number of classes being used (primary forest, non-forest, secondary forest, water, cloud, and shadow), the project is able to achieve high categorization and change detection accuracies.

Because all enhancement methods are based on pixel-wise operations or scene-wise plus pixel-wise operations, accuracy in image registration and co-registration is more critical for these methods than for other methods.

OPTIMIZING FOR DIGITAL CHANGE DETECTION:

NALC SCENE SELECTION AND PREPROCESSING

The basic requirement for remote sensing land cover change detection is the availability of two dates of imagery upon which the same area of land can be observed. Depending on the characteristics of the two data sets, change detection can be either an easy or difficult task. The NALC data sets have been selected and assembled in order to simplify the detection of change using digital image processing. Below is a description of some of the complicating factors which tend to make change detection more difficult, with indications of the design features of the NALC project which address the difficulties.

The accurate detection of land cover change using remotely sensed data can be complicated by the following factors:

1) Spatial resolution and spectral bandpass differences between images acquired with two sensors complicates the direct comparison or the digital analysis of the data to detect change. With the spectral bandpass differences, the detectable land cover classes for the two dates of imagery may not be comparable. Land cover classes that are distinct when observed with one sensor may be indistinguishable with a sensor having broader or fewer numbers of spectral bands. If there are substantial spatial resolution differences between the two input images, ground features may be visible in one data set and undetectable in the other. In the NALC project we eliminate problems that could be introduced due to spatial resolution and bandpass differences by working exclusively with Landsat MSS, a sensor series that has provided consistent spatial and spectral characteristics for a twenty-year period.

2) Variations in the radiometric response of a sensor can complicate change detection by requiring some form of image-to-image equalization prior to the change detection or by requiring the use of a post-classification change detection approach. This factor is important to the NALC project because we are working with data spanning a twenty-year period and collected by five different MSS sensors (Landsats 1-5). Although each of the MSS sensors were calibrated before launch, it is known that their response drifted over time and that there is no adequate way to calibrate the data to radiance units without extensive ground based efforts. It is clear that the change detection procedures used by the NALC program must explicitly address the radiometric differences to be encountered in performing change detection without calibrated input data.

3) If clouds are present in images from one or both dates, it is impossible to detect land cover change between the two dates of imagery where clouds occur. To minimize the effects of clouds, low cloud cover was one of the primary factors directing the selection of scenes for the NALC project.

4) Variations in solar irradiance, solar zenith angle, and solar azimuth will affect scene brightness levels and the location of shadows. The NALC project has attempted to reduce these effects by selecting scenes for the three time periods which were acquired at or near the same Julian date in order to match the solar conditions as far as possible. In general, high sun angles (low amount of shadowing) are better than low sun angles for the detection of land cover change.

5) Variations in atmospheric effects (scattering and absorption) can affect scene characteristics sufficiently that they must be considered in evaluating change detection methods. The NALC data sets have been visually screened to remove scenes where within-

scene atmospheric variations are obvious. By assuming that the atmospheric effects on the selected scenes are uniform across the entire scene area, it is possible to partially compensate for scene-to-scene variations in atmospheric effects by scene-to-scene brightness equalization. The coregistration of the NALC MSS products will also help to compensate for topographic variations which alter atmospheric path length.

6) Phenological variations in vegetation result in large changes in the reflectance patterns of the land surface. If images of leaf-on and leaf-off conditions are compared, whole regions can appear to have been "deforested". The scene selection process of the NALC project has attempted to minimize this problem by selecting scenes from the same time of year for each of the three time periods. In some cases it was not possible to do this due to the lack of appropriate archive data.

7) Spatial misregistration of images will tend to reduce the accuracy of any digital change detection effort. These effects are most severe on the change detection techniques using enhancement. The NALC data sets are digitally coregistered, with accuracies on the order of half a pixel or less, creating data sets that can be analyzed for change with minimal errors due to misregistration.

NALC Change Detection Strategy

The basic NALC data set consists of three dates of Landsat MSS data, from the early 1970's, mid-1980's, and early 1990's, plus ancillary data such as digital terrain. In performing the change detection for the NALC project two output products will be generated: 1) Land cover change from the early 1990's to the early 1970's; and 2) Land cover change from the early 1990's to the mid-1980's. The output products should show the location of the changes as well as the nature of the change (e.g., conversion of woody to herbaceous).

NALC Change Detection Procedure

The NALC Landsat MSS triplicates have been selected from the available archive of data held by the USGS EROS Data Center. A considerable effort has been put into selecting scenes with low cloud cover and at or near the same date for all three time periods in order to have data sets optimized for digital change detection. However, in the extreme southern portions of the project area (southern Mexico, Central America, and Caribbean Islands) it was frequently not possible to find low cloud cover scenes at the same time of year. Cloud reduction compositing is being used to assist in the development of triplicates which are matched to the same time of year. However, there are numerous triplicates which will not be closely matched.

An example is given below for Path 21, Row 47 in southern Mexico:

21/47	92/04/29	LE84357515342x0
21/47	84/11/25	LM85026915590x0
22/47	74/02/15	LM8157215552500
23/47	78/09/17	LM83019615545x0

In this circumstance, it may be necessary to use a post-classification change detection approach to derive the land cover change products.

For the majority of the NALC triplicates, it has been possible to find data in the archive having low cloud cover and closely matched dates for use in the triplicates. An example of this type of triplicate is given below for Path 45, Row 29 in Oregon:

45/29	92/08/03	LM85307718130x0
45/29	86/08/19	LM85090118114x0
49/29	72/09/02	LM8104118265500
48/29	72/07/27	LM8100418210500

In this case, and in the case of the majority of the NALC triplicates, it should be possible to use an enhancement technique to identify areas where change has occurred. Then the change areas would be labeled using the same labeling procedures used in developing the current land cover product.

The first choice of the NALC change detection will be to use an enhancement method to locate pixels where land cover change has occurred. However, because of the presence of triplicates which contain data from diverse times of the year, it will be necessary to have a post-categorization method developed. We are therefore developing a dual-track research plan to develop a suitable enhancement method and protocols for post-categorization change detection.

NALC Change Detection Evaluation Criteria

NALC has two groups of criteria: programmatic criteria and technical criteria, for evaluating change detection techniques.

For the change detection procedure using enhancement, the criteria are as follows:

Programmatic criteria: 1) The method must be relatively sensitive to deforestation and/or loss of vegetation - the primary target of the NALC project; 2) the method must be simple in concept and have been successfully tested widely, so that it can be accepted by a wide spectrum of application scientists; 3) the computation should be straightforward and unambiguous to perform in various computational environments; and 4) this method should require a minimal amount of expert (human) intervention so that it can be applied to a large number of scenes.

Technical criteria: 1) The method must be accurate; 2) the method must be relatively insensitive to sensor effects and atmospheric effect; and 3) the method must work in a wide range of geographic regions.

Since the post-categorization method will only be applied to a limited number of scenes and areas, the speed and simplicity of the method will no longer be emphasized. Instead, the following will addressed: 1) This method must be able to provide detailed and accurate class to class change information; 2) this method should require minimal human intervention so to optimize automated processing; and 3) this method should provide highest possible categorization accuracy.

NALC CHANGE DETECTION RESEARCH:

TECHNICAL WORK PLAN

This work plan describes the study sites and change detection methods to be used in developing the standard procedures to be used in the rest of the NALC project.

Study Sites

Three diverse areas have been selected for conducting change detection research for the NALC program.

Washington, D.C. - Path 15, Row 33: This is an area that has undergone substantial urban and suburban expansion during the past two decades. Many forest areas surrounding Washington, D.C. have been converted to residential, commercial, and industrial sites. The exact magnitude of these land cover changes has yet to be determined. This Path/Row image scene lies within the Chesapeake Bay Watershed, which has been an area of active USEPA Environmental Monitoring and Assessment Program (EMAP) research. During the past two years a current land cover map was produced by EMSL-LV using recent Landsat Thematic Mapper (TM) data as part of the EMAP Landscape Characterization program. The NALC project change detection research pilot in the Washington, D.C. triplicate will make use of the EMAP land cover data set as a source of validation data. As an additional validation source, we will obtain the coastal land cover change data for this area produced from Landsat data by the NOAA Coastwatch-Change Analysis Program (C-CAP), which was produced using a pre-categorization change detection method.

Central Oregon - Path 45, Row 29: This scene covers a forested transect across the Western flank and crest of the Cascade Range, plus arid areas, with irrigated agriculture to the east of the Cascades. The forests of the Cascades include some old growth forests, plus numerous secondary forests which have been disturbed through forest harvesting. All conditions of forestation exist, ranging from barren to closed canopy forests.

Southern Mexico - Path 21, Row 48: This scene centers on a mountainous tropical forest region, on the Mexico-Guatemala border. On the Mexican side there has been extensive conversion of forest for use in agriculture and timber production. There has been much less activity on the Guatemalan side. At the northern end of the scene there are extensive wetland forests which have been cut and drained. The area is covered by detailed 1:250,000 scale Land Use - Vegetation maps produced in the early 1980's by the Mexican government.

Methods to be Tested and Evaluation Criteria

In each of the three study areas, photo interpretation will be used to outline and categorize areas of land cover change. We will use the digitized photointerpretation results as a basis for comparing the results from the digital change detection methods. Because of the dual track approach required for change detection in the NALC project, the use of both enhancement and post-categorization methods will be investigated.

The areas of change delineated by each of the investigated approaches will be digitally compared to the land cover change results obtained through photointerpretation of the same scene area to produce percent accuracy values. The change detection methods will be evaluated based primarily on criteria stated above.

Post-Categorization Change Detection

Protocols for the post-categorization change detection will involve the repeat of the NALC standard categorization results, which are being developed to produce current land cover data sets. These procedures will be repeated for the other two time periods. Then the areas of change will be extracted by comparing the early 1970's and mid-1980's land cover categorizations with the current land cover.

Enhancement Techniques For Change Detection

Because most of the NALC triplicates have been optimized for use in enhancement change detection methods, an emphasis will be placed on experimentation with these approaches. Because of atmospheric and sensor related radiometric response differences, we will focus on procedures which have some capacity to normalize the radiometry of the data prior to locating change pixels. Our review of the literature suggests that three enhancement techniques have built in capability for normalizing or equalizing the radiometry of scenes: Vegetation index differencing; regression analysis; and principal components analysis.

Change Detection Through Vegetation Index Differencing

The development of vegetation indices from spectral reflectance values is based on the differential absorption and reflectance of energy by vegetation in the red and near-infrared portion of the electromagnetic spectrum (Derring and Haas 1980). In general, green vegetation absorbs energy in the red region and is highly reflective in the near-infrared region (Anderson and Hanson 1992). A number of vegetation indices have been formulated and utilized for monitoring vegetation change. Of these vegetation indices, NDVI has been used most widely for monitoring terrestrial vegetation dynamics (Townshend and Justice 1986, Eidenshink and Haas 1992, Tappan et al. 1992). The NDVI compensates for some radiometric differences between images; however, it does not completely remove radiometric images that are being compared. The difference in the NDVI values of two images in certain cases responds to changes in land cover (Nelson 1982 and 1983, Banner and Lynham 1981). Singh (1989) concluded that NDVI differencing was among the most accurate of change detection techniques.

In our change detection pilot data sets, the NDVI values will be computed for each date of imagery. The early 1970's and the mid-1980's NDVI images will be subtracted from the 1990's NDVI image to create two NDVI difference images. These will be compared to the photointerpretation results in order to calculate the accuracy of the NDVI differencing approach.

Change Detection Through Principal Components Analysis

Principal Components Analysis (PCA) involves the reorientation of axes of an input data set, creating output Principal Components (PC) data sets. In our case two coregistered MSS images will be input as an eight band or eight axis image. Because of the autocorrelation of the original data, there is an elongated cloud of distribution of data located in the axis of each data set. The PCA will orient the first axis of the output data through the central core of the input data cloud. The second axis will be perpendicular to the first and will be directed through the next major direction of variance in the data set. The PCA can continue to establish new axes, until the number of output axes equals the number of input axes. The first PC normally contains the overall scene brightness variations which are in common between all the input bands. The second, third, and fourth (and sometimes higher) PC images frequently contain information on pixels which changed in reflectance between the two dates of imagery (Byrne et al. 1980, Richardson and Milne 1983, Fung and LeDrew 1987). The last PC image would be expected to contain random noise that existed in one image relative to the other.

In scenes with cloud cover and associated shadowing, it will be necessary to screen out the cloud and shadow areas to exclude them from the PCA. Clouds or shadows which are present in one date and absent from the second date will tend to redirect the axes which would otherwise be established due to reflectance changes due to land cover change.

Part of the PCA algorithm involves the normalization or equalization of the input data, thereby reducing atmospheric and sensor radiometric response differences from the output PC images. This is one of the characteristics required for the NALC change detection, making PCA one of the leading candidates for the standard change detection method for use in the NALC project.

Color composite images will be made from combinations of the second, third, fourth, and higher PC's. Areas of change will be identified from these color composites and the accuracy of these PCA based change detection areas will be compared with the results from the photointerpretation.

Change Detection Through Regression Analysis

The results of Hall et al. (1991) indicated that band-to-band radiometric rectification or equalization, as a distinct preprocessing step, can substantially improve the accuracy of the image differencing approach to change detection. The methods of Hall et al. relied on the manual extraction of pixels which were consistently bright and dark pixels from the image, to obtain digital number values for use in regression analysis. The regression line between the bright and dark pixels was taken to be the line of "no-change". Pixels which departed from the regression line were taken to be pixels in which some type of land cover change occurred.

We plan to experiment with a modification of the approach described by Hall et al. to make the procedure automated, and remove the reliance on bright and dark ground targets which occur in each date of imagery. For each pair of MSS scenes, four band-to-band (e.g., band 1 versus band 1) scatter diagrams will be prepared using a random subsampling of the image pixels. Early experiments with this approach indicate that in each scatter diagram a diagonal axis of data points will appear. This is the axis of "no-change". Clouds and cloud shadow present in one image and absent in the second image will tend to form their own axes, parallel to the diagram axes (Figure 5). Pixels which change in reflectance between the two dates due to land cover change will not fall on the diagonal scatter diagram axis (the "no-change" axis). By determining the location of the "no-change" axis with linear regression, it is possible to calculate the orthogonal distance from the "no-change" axis for each pixel in the image, creating an output image depicting the reflectance changes which occurred between the two dates for a particular band. By repeating this procedure with all four bands, four output change images will be created from the eight input bands. As with the PCA approach, the cloud and cloud shadow areas would need to be excluded from the regression analysis.

As with the PCA approach, color composite images will be made from regression analysis output images. With four output change images there are only two three-band color composite combinations possible: 1, 2, and 3 or 1, 2, and 4. Areas of change will be identified from these color composites and the accuracy of these PCA based change detection areas will be compared with the results from the photo interpretation. It may also be possible to utilize a statistical test such as Chi-square.

Change Detection Study Time Frame

NALC change detection study is designed to investigate and select the optimal change detection techniques for the NALC project. The time frame for change detection study is as follows:

September 1992 - November 1992: Change detection literature review. During this period, an extensive literature review on change detection had been conducted. A detailed internal report on present change detection techniques has been accomplished.

November 1992 - February 1993: Commence the testing of techniques with small scale testing. During this period, majority of the present change detection techniques has been tested in a subscene Chiapas, Mexico. The NALC project has become conceptually familiar with many of present change detection techniques. Selected testing results have been internally reported to NALC.

February 1993 - April 1993: NALC change detection strategy and procedure design and final refinement. This is done through more review, testing and personal contacts with change detection community.

May 1993 - November 1993: NALC pilot change detection experiments. The selected change detection techniques are to be tested in three NALC pilot areas. A draft report regarding the result of these experiments will be completed by November 12, 1993.

Change Detection Correspondences

During our process of soliciting feasible change detection techniques for NALC, the following scientists have shared with us their knowledge and experience on change detection. Many of them have kindly offered us their suggestions on possible change detection techniques for NALC.

Ford A. Cross, National Marine Fisheries Service, (919) 728-8724. Cross is the Director of the CoastWatch Change Analysis Project (C-CAP), NOAA Coastal Ocean Program. The change detection analysis is primarily based on a post-classification comparisons.

Jerry E. Dobson, Oak Ridge National Laboratory, (615) 574-5937. Dobson is the principal investigator of NOAA CoastWatch Change Analysis Project and designed the change analysis procedure for the program.

Charles R. Larson, Hughes STX Corporation, EROS Data Center, (605) 594-6504. Larson had performed raw image differencing technique to monitor surface change during the 1991 Persian Gulf War period.

Bill Lawrence, Geography, University of Maryland at College Park, (301) 405-6809. Lawrence is currently involved in the NASA Landsat Pathfinder - Tropical Deforestation Project in Central Africa. This project is planning to conduct post-classification change detection on classified image maps obtained by a multiple threshold technique.

Richard A. McKinney, Hughes STX Corporation, EROS Data Center, (605) 594-6500. McKinney had conducted NDVI differencing change detection for continental America for USGS.

Douglas Muchoney, The Nature Conservancy, (703) 841-5300. Muchoney suggested that principal component analysis could significantly reduce sensor and atmospheric effects from the raw images, and therefore it would worth to test some principal component analysis in some NALC pilot areas.

David Peterson, NASA/Ames Research Center, (415) 604-5899. Peterson had used image regression technique with chi-square for detecting changes.

Paul M. Seevers, Hughes STX Corporation, EROS Data Center, (605) 594-6010. Seevers had applied a sequential change detection techniques to the Dallas - Ft. Worth region as well as in the Mt. St. Helens region.

Ed Sheffner, TGS Technology, NASA/Ames Research Center, (415) 604-6565. Sheffner suggested that image regression might serve the purpose of change detection of NALC, or may be used as a temporal equalization technique.

Ashbindu Singh, GRID, United Nations Environmental Program, EROS Data Center, (605) 594-6105. Singh has reviewed (1989) many of the present change detection techniques and suggested that raw image differencing, NDVI differencing, image regression, and principal component differencing produced higher accuracies for change detection.

David Skole, Complex System, University of New Hampshire, (603) 862-1792. Skole is the leader of NASA Landsat Pathfinder - Tropical Deforestation Project in Southeast Asia. This project will use change detection methods similar to the Central Africa project methods.

John Townshend, Geography, University of Maryland at College Park. (301) 405 -4050. Townshend had suggested to us that we have more intense contact with the scientists in the change detection community.

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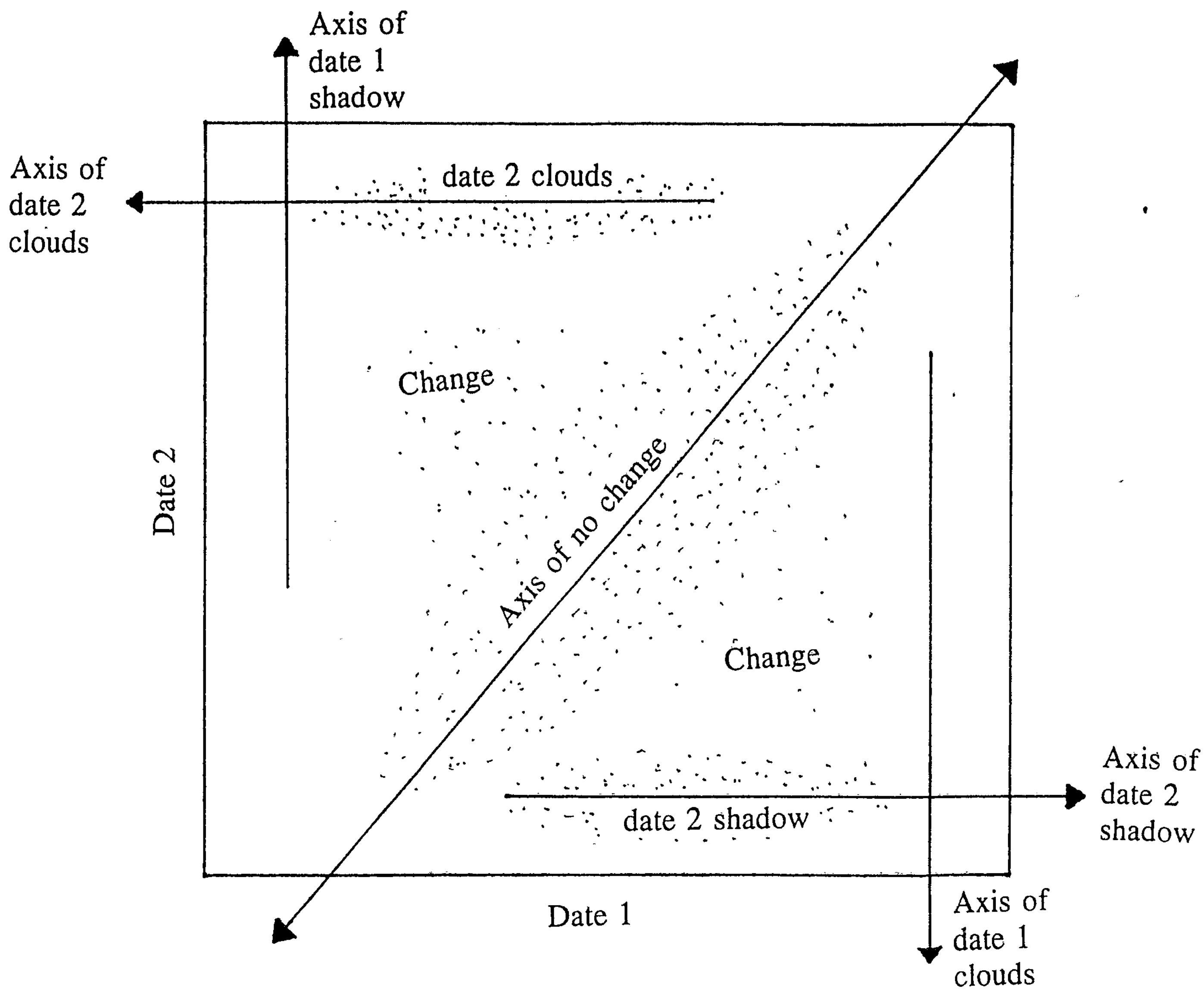
Figure 5. **Schematic Scatter Diagram of Date 1 Versus Date 2 for a Given Band**



NALC QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and quality control (QA/QC) procedures will be developed and implemented to insure and verify that NALC products meet the project's data quality objectives stated herein. Initial QA/QC procedures have been established and will be tested in the pilot projects. The QA/QC procedures will be evaluated and revised during the pilots. At the completion of the pilots a final QA/QC guidance document will be prepared. The principal elements of the NALC QA/QC include: Standard operating procedures for all aspects of the data processing; quality control checks during data analysis; implementation of data tracking forms to document all procedures executed on each MSS scene; verification and validation of spatial accuracies; acquisition of verification data; and accuracy assessment of categorizations.

Standard Operating Procedures

Each organization participating in NALC is in the process of developing standard operating procedures and a report documenting those procedures. It is anticipated and expected that these reports will be revised frequently during the first year of the project. The NALC components that require standard operating procedures include triplicate selection and production, georeferencing, image categorization and change detection.

Quality Control

Quality control procedures will include the validation of initial image spectral quality, location and date of image collection, and adequate georectification. Both EMSL-LV and the EROS Data Center have developed internal quality control checks for previous projects that will be applied to NALC. Aspects of the quality control procedures cross over into data analysis tracking and spatial accuracy validation, both of which are discussed in more detail after this section. The importance of quality control procedures is to establish checks to minimize and identify data degradation at the earliest stage of analysis. It is important to document the source of data degradation and probable impacts on the final products.

Data Analysis Tracking

Data analysis tracking includes documentation of all analyses implemented on the data including quality control checks. Forms designed to track the data can provide a means of post-analysis error evaluation. A series of these forms have been developed at EMSL-LV for the NALC pilots. An example of these tracking forms is located at the end of the Image Categorization Section. All data tracking forms will be archived (either in digital or hardcopy format), by each organization participating in NALC, for the duration of the project and for a minimum of two years after project completion.

Spatial Accuracy Verification

Spatial accuracy of the MSS georectification includes both a verification of each scene and a validation of every tenth scene. The EROS Data Center performs a verification check of their georectification process on every scene as part of their internal quality control. They are continuing to perform the same verification process for NALC. After the MSS scenes are received at EMSL-LV, every tenth scene's accuracy will be independently validated.

The EROS Data Center uses USGS 7.5 minute quadrangle maps or the best available maps to select control points for image-to-map georectification. In the U.S., every ninth map across the scene is selected for the georectification process. A total of 25 to 40 maps are available for control point selection per MSS scene. One point per map is selected in both the image and map. Only those points for which the residuals are less than one second (i.e., +/- 80 meters or approximately 1.5 pixels) are used for georectification. A minimum of 6 control points are required per scene, although 10 to 12 points are preferred. For the verification process different maps are randomly selected and a total of 6-7 points are randomly selected. The map and georectified image coordinates are statistically compared for these points. Again residuals must be under 1.5 pixels.

Georectification for NALC involves image-to-image as well as image-to-map rectification. The 1980s MSS scene is first registered to USGS maps; then it is used as the "map base" for georectification of the 1970s and 1990s scenes. The image-to-image rectification is performed in a different manner than the image to map, but the verification process is the same as that stated above. Initially for the pilot areas, verification of every fifth scene will be performed for the image to image georectification. If the spatial data quality objectives are met for the pilot areas, then the number of scenes that will be validated will be reduced to every 10th scene.

The validation begins by examining a list of map control points used by EROS Data Center to georectify the scene. This will prevent selection of a georectification control point for the validation, i.e., use of georectification control points in the validation process would result in a positive bias. Then a random selection of at least four maps that were not used by EDC in the rectification process is made. At least three points per map that are identifiable in the imagery are randomly selected. The map and image coordinates for the point are statistically compared. An RMSE of +/-1.0 (60m) pixel has been established as the spatial accuracy data quality objective (DQO) for the image to map rectification and +/-0.5 pixel (30m) for the image-to-image rectification. Therefore, in comparing an image rectified by another image to a map base, the total spatial error should not exceed +/-1.5 pixels (i.e., +/- 1.0 pixel for the image to map plus +/-0.5 pixel for the image-to-image). If the RMSE is larger than +/-1.5 pixels, the EROS Data Center will be contacted. If, after evaluating the georectification process, it is determined that there are insufficient identifiable points to produce a better rectification, the scene will be used, but it will be flagged to identify that the spatial accuracy is less than the DQO.

Thematic Accuracy Assessment

The purpose of performing an accuracy assessment of the NALC categorized data is twofold. General scientific ethics and EPA policy require that all final products have a stated known accuracy. Most importantly for NALC, the accuracy assessment will enable a more precise estimate of the areal extent of each category; in other words, an assessment of categorical accuracy is more important than, and prevails over the necessity for an assessment of overall map accuracy. Categorical accuracy information will be critical in the development of realistic and reliable continental carbon and climate models. Several methods have been presented in the literature for improving area estimates of categorized data (Card 1982, Hay 1988, Jupp 1989, Conese and Maselli 1992, Czaplewski and Catts 1992). All methods presented by these authors use the error matrix derived from an accuracy assessment to calculate corrected or unbiased estimates of individual category areal extent. Each of these authors also states that the choice of sample design and sample size is critical to the valid use of an error matrix for improving area estimates. The following text describes proposed methods for conducting a pilot accuracy assessment that will result in a statistically valid error matrix. (NOTE: These methods are not necessarily the methods that will be used for all NALC categorization accuracy assessments. They are test methods for the pilot that will enable the NALC team to evaluate categorical error variances, reasons for errors, the applicability of different scale verification sources, and the overall efficiency and cost effectiveness of the assessment approaches tested. Future pilots based on this initial assessment will further test modified accuracy assessment procedures.)

Field Verification

As stated previously, Landsat MSS data will be used for the categorization. The resolution of these data combined with the level of categorization indicate that a detailed field verification may not be required to perform a statistically sound accuracy assessment. Therefore, the verification effort will be based primarily on MSS image interpretation and aerial photointerpretation with very limited examination of actual field sites. A three-band color composite of the MSS images will be used with ancillary data as a primary verification source. While high-resolution aerial photographs would be the optimum verification source, it is recognized that for some areas of the U.S. and almost all of Central America, aerial photographs from a compatible time period will not exist and acquisition of new aerial photographs is cost prohibitive. Whenever possible, aerial photographs will be used as the primary verification source. Field sites will only be examined as a validation check of the MSS/photographic interpretation sites. Whenever possible, all interpretations will be performed by experienced image interpreters or photointerpreters who are not directly involved in the NALC project. However, there may be some cooperators from Central America who will not have the resources available for an independent interpretation. In either case, care will be taken to ensure that the interpreters do not have access to the categorized image as this may cause bias in the interpretation. During the pilot projects, testing of the different sources and scales of verification data will be evaluated. In particular, the Chesapeake Bay pilot area will be verified with MSS image interpretation, aerial photointerpretation, and a field validation. The results and conclusions of this effort will aid in the determination of a final sample scheme for NALC accuracy assessments.

Sampling Design

Sampling design includes the choice of sampling scheme, i.e., random or systematic, and identification of an appropriate sample size. The remote sensing literature states advantages and disadvantages of both random and systematic schemes and is divided in its support of each scheme (see Congalton, 1991 for a review of this literature). However, it is recognized that the choice of an appropriate sampling scheme is based on the goals of the accuracy assessment. As stated previously, the goals of the NALC thematic accuracy are to state the accuracy of the mapped categories as well as to provide the necessary statistics to improve categorical area extent estimates. Prisley and Smith (1987) state that "<u>A crucial assumption in this use of error matrices</u>," i.e., to improve areal extent estimates, "<u>is that the distribution of error in the contingency table is representative of the types of misclassification made in the entire area classified</u>." Card (1982) also states that the sampling design employed in the collection of verification data dictates how the error (or confusion) matrix may be composed to provide conclusions about the entire population.

The choice of a sampling scheme for the NALC accuracy assessment is based on the following requirements and assumptions:

1) Individual category accuracies must be determined, including errors of omission and commission;

2) the variance of categorical misclassification is unknown, i.e., no previous pilots have been performed to provide an estimate of the variances;

3) the existence and magnitude of misclassification spatial autocorrelation is unknown, but one is assumed to be present;

4) the possability of visiting 100% of the verification sites on the ground is logistically and cost prohibitive;

5) the availability of aerial photographs for verification from a similar date or season as the MSS acquisition is highly improbable for large portions of the NALC project area;

6) the MSS data has already been acquired, therefore it is impossible to acquire simultaneous "in the field" data;

7) each MSS scene will be categorized individually for the Chesapeake Bay pilot, i.e., each scene will have cluster statistics generated for it independently of the other scenes within the pilot area. This will probably result in different misclassification variances for each scene;

8) and the result of the accuracy assessment must be a statistically valid error matrix that may be effectively used to better estimate the area of individual categories.

Sampling Scheme

While numerous papers may be found that discuss sampling schemes in the remote sensing literature, only two studies to date (Congalton 1988 and Stehman 1992) have compared several sampling schemes using the same categorized remotely sensed data. Congalton recommends the use of a simple random or stratified random sample while Stehman is a proponent of systematic sampling schemes. The two papers do, however, have similar conclusions. First, both authors state that the choice of sample scheme must be based on project objectives. The objectives of the assessment and the statistical approach drive the choice of sampling scheme.

Secondly, both authors indicate that periodicity or spatial autocorrelation of misclassification errors can significantly and negatively impact the precision of a systematic sample. Stehman (1992) states that systematic sampling designs should not be used if periodicity is suspected, unless the nature of the periodicity is understood well enough to avoid an unfavorable sampling interval. Congalton (1988) examined three images of differing landscape pattern types, namely, forest, range and agriculture. In each case the misclassification errors were found to be significant and positively spatially correlated. The spatial autocorrelation of NALC categorization errors will be unknown until after the first accuracy assessment is performed. Therefore, until accuracy assessment data is acquired and estimates of spatial autocorrelation may then be calculated, spatial autocorrelation must be assumed.

Another concern in selecting a sampling scheme is how well that scheme estimates variance. Stehman (1992) states that estimation of error variance may be problematic for systematic samples. Cochran (1977) states that there is "no trustworthy method for estimating $V(\bar{y}_{sy})$ from the sample data is known" for systematic samples. $V(\bar{y}_{sy})$ is the variance of the error mean. Rosenfield (1982) agrees with and sites this statement from Cochran. Congalton (1988) states that simple random sampling provided good estimates of the mean error and variance for each image type (forest, agriculture and range). He further states that "stratified random sampling also performed well and should be used especially when it is necessary to make sure that small, but important, areas are represented in the sample," and that systematic samples should only be used with caution, i.e., in situations where the variance and spatial autocorrelation are well understood.

As stated previously, the primary objective of the accuracy assessment is to provide estimates of individual category accuracy in the form of an error matrix. The error matrix must address errors of omission and commission so that it may be used to calculate better estimates per category. Given these constraints, the sample design selected must provide the most precise and unbiased estimator of individual class accuracy. Also, the NALC categorization process will cluster each Landsat MSS scene independently. Therefore, a between-scene error variance should be accounted for in the pilot sample design. Based on the remote sensing and statistical literature, a stratified random sampling scheme will best meet the needs of the first pilot and will be used for the Chesapeake Bay pilot on a scene by scene basis. After the assessment data is acquired, a careful evaluation of scene to scene and categorical variances will be made to determine the most appropriate and cost effective sampling scheme for future NALC accuracy assessments. Until the variances resulting from the NALC categorization procedures are estimated and understood, the choice of a systematic sample may result in an imprecise and/or biased estimate of the error.

Sample Size

The number of samples to be selected for verification is dependent on the goals of the project. If only a right-wrong assessment is needed then the binomial distribution or normal approximation equation may be used to calculate the sample size (van Genderen and Lock 1977, Rosenfield and Fitzpatrick-Lins 1982). However, the binomial distribution does not provide a sufficient sample size to construct a statistically valid error matrix.

Fitzpatrick-Lins (1981) and Borella et al. (1982) used the normal approximation equation and binomial distribution, respectively, to calculate sample size for their accuracy assessments. In both cases, the sample sizes were insufficient to construct complete error matrices. An appropriate distribution to calculate sample size for development of an error matrix is the multinomial (Rosenfield 1982). However, correct usage of the multinomial distribution requires information on the expected error and the variance associated with that error. Since the categorization methodology has not been thoroughly tested prior to this pilot there are no variance estimates available. Initial calculations using the multinomial equation presented in Rosenfield (1982) and the preliminary results from a previous EMSL-LV categorization indicate that a sample size between 137 to 163 samples per category is appropriate. The equation is depicted below.

$$n = \chi^2_{1,1-\alpha/k}\, p_j(1-p_j)/\delta^2_j$$

$\underline{n}$ = the sample size
χ^2 = the Chi Square distribution
$\underline{\delta_j}$ = the half width of the desired confidence interval for a particular category $\underline{j}$
$\underline{\alpha}$ = the Chi Square distribution tail; this definition is not directly stated in Rosenfield (1982), but is surmised from the numbers presented
$\underline{k}$ = the number of categories
$\underline{p_j}$ = the estimated proportion of correctly categorized pixels for a particular category $\underline{j}$; this definition is not directly stated in Rosenfield (1982), but is surmised from the text

However, the EMSL-LV data does not provide a sufficient measure of error variance and questions arose over the proper use of the multinomial equation presented by Rosenfield (1982). Further examination of the multinomial distribution and confirmation of the multinomial equation presented by Rosenfield (1982) will be performed prior to finalization of the NALC pilot accuracy assessment procedures. As a minimum, Hay (1979) and Congalton (1991) recommend that sample size per class should be at least 50 to test the accuracy of determinations, i.e., not only right versus wrong but examine the multiple classes of wrong.

Another approach used to determine sample size is an area weighted sample. This may be an overall area weighting or area weighting by category. The overall area weighting specifies a total sample size that represents a given percentage of the entire population or image. The categorical area weighting is a stratification of the overall area weighting wherein the class with the largest area has the largest number of samples again based on a given percentage. Intuitively, the random or systematic selection of points from a population should yield similar results whether or not the selection process is stratified by category. Congalton (1988) recommended that at least one percent of the entire image be sampled for agricultural, range, and forested image subsets. He also states that his results indicate a larger sample size should be used if a stratified systematic unaligned or systematic sampling scheme is used.

Based on the information above the NALC Chesapeake Bay pilot sample size will contain no fewer than 50 points per category with a maximum number of points per category as determined by the multinomial distribution. If the error variances for individual categories or scenes are higher than anticipated, additional samples will be taken (i.e., a double sample) to better define the variance. Based on the final results of the pilot, a recommendation will be made for the appropriate choice of sample sizes for future NALC categorization accuracy assessments.

Verification Procedures

After the verification sites have been selected, MSS Landsat three-band color composites will be interpreted. The pixel closest to the accuracy assessment sample site will be used as the verification center point. A square area consisting of two pixels per side from the center of the "sample" pixel will be interpreted, i.e., approximately a 5x5 pixel area. A draft form for the MSS verification is displayed in Table 7. EMSL-LV has in its possession aerial photographs covering a significant portion of the Chesapeake Bay watershed. Any aerial photographs coinciding with a sample site will be interpreted to evaluate the effect of scale and as a validation check of the MSS interpretations. Location of the coordinates on the photographs may be performed by appropriate scaling, and using maps and analytical stereoscopes. Table 8 lists the information that will be documented for photointerpreted site. The verification forms should be filled out as completely as possible for each site. There will probably be some areas where changes have occurred since the date of photograph acquisition or field visit. For areas where changes are known to have occurred, the interpreters should consult with people familiar with the area to collect up-to-date information. The source of this type of information should be documented on the verification forms.

A field check will be performed for four randomly selected verification points per category as a validation check of the interpreted data. Therefore, only those points that were included in both the MSS and photo interpretation will be used for this selection. The field check may be performed using one of two methods: walking the site area or flying over the site at a low altitude. Low altitude aircraft will primarily be used in areas with no access or prohibitively dense vegetation. Maps, GPS units, and/or other surveying techniques may be used to identify locations. The method of field checking will depend upon the site conditions, access, and availability of resources. Therefore, choice of method will be based on local conditions and the capability of other NALC cooperators. If access to any of the sites is prohibitive, then another site will be randomly selected to replace it (i.e., sampling with replacement). A verification form displayed will be used to record as much detailed site information as possible and will be compared to the MSS and photo interpretation forms for that site. In addition, 35mm photographic slides will be acquired at field sampling sites. The field form level of detail will provide more information than is necessary for a validation check. However, previous experience has shown that this level of detail is beneficial for evaluating sources of error. Field crews will consist of at least two individuals per team; at least one of the team members will have expertise operating GPS and one with expertise on the local biota. If there are significant differences among the different scales of verification data, the field data and slides will be used to evaluate possible reasons for the differences. If possible, a procedure for correcting the differences will be developed.

All individuals employed to perform the verification / validation of thematic accuracy will have expertise in the appropriate areas and whenever possible, will be external to the NALC project. In addition, these individuals will not have access to the categorized MSS images to reduce the likelihood of positive or negative biases.

Table 7.

NALC MSS Interpretation Verification Form

Analyst: ____________________________________

Date of Interpretation: _________

Verification Site Information

MSS Scene ID#: _____________ Scene Date: _______

Verification Site ID#: _________

Scene Coordinates of Verification Site:

____

Bands and enhancements used for image color composite: Red ____ Green ____ Blue ____

____

Ancillary Data (list any maps, photographs, local experts, etc.)

____

____

____

Interpretive Information

Describe the size, shape, color, texture, and types of features within the verification site:

____

____

____

List Appropriate Category Name:

____

Second choice category name (if applicable): ______

Table 8.

NALC Photographic Interpretation Verification Form

Analyst: ______________________________

Date of Interpretation: ________

Imagery Date: ___________ Film type: ____________

Frame #: ______________

Scale: __________ Source: _____________

Stereo pairs: ___ yes ___ no

Verification Site Information

MSS Scene ID#: __________ Verification Site ID#: ____

Photograph Frame #: _______

Method of locating verification site on the photograph:

____

____

____

Interpretive Information

Describe the size, shape, color, texture, and types of features within the verification site:

____

____

____

____

List Approprite Category Name:

____

Second Choice Category Name
(if applicable): ____________________________________

Thematic Accuracy Assessment Reporting

A confusion (error) matrix and its associated parameters, errors of commission and omission and overall accuracy, will be calculated as described by Story and Congalton (1986). In the matrix, the verification data will be compared to the categorized data as columns and rows, respectively. The cells within the matrix indicate the number of pixels categorized as category a through n that correspond to the verification sites as labelled category a through n. For instance, in the example error matrix (Table 9) for the 100 verification sites examined for category a, 65 were correctly categorized in the remotely sensed data, 25 were incorrectly categorized as category b, and 10 incorrectly categorized as category c. The diagonal from the upper left to the lower right represents the number of image pixels correctly categorized and, when divided by the total number of pixels verified, yields the overall accuracy of the categorization. There are two ways to calculate the accuracy of individual categories and they are termed user's and producer's accuracies or errors of commission and omission, respectively.

Table 9. An Example Error Matrix Table

CATEGORIES	Reference a	Reference b	Reference c	User's Accuracy
Image a	65	5	10	65/80 = 0.81
Image b	25	85	15	85/125 = 0.68
Image c	10	10	75	75/95 = 0.79
Producer's Accuracy	65/100 = 0.65	85/100 = 0.85	75/100 = 0.75	225/300 = 0.75

Sum of major diagonal = 225 Overall accuracy = 225/300 = 75%

User's accuracy or errors of commission may be defined as whether a categorized pixel within an image actually represents what is on the ground or not, or how accurately or reliably the categorized map represents the area. Producer's accuracy or errors of omission approach the question of categorized accuracy from an opposite direction, that is how well a sample site or area can be represented by a categorized image or map. The example error matrix demonstrates that the two calculations do not yield the same results. Both of these types of individual category accuracies will be presented to provide a more complete identification of the types of errors present in the categorization. In addition, the Kappa coefficient (Congalton 1991) will be calculated. Kappa measures the relationship of non-random categorization agreement versus expected disagreement. It will be used to monitor trends in categorization reliability from one categorization to another. The Kappa coefficient equals zero when the agreement between the categorized data and ground truth equals chance or random agreement. Kappa increases to one as chance agreement decreases, and becomes negative as random assignment of categories occurs. Kappa equal to one occurs only when there is perfect agreement. After accuracy assessment calculations are completed an evaluation will be performed to determine where the errors occurred. In particular, comparisons will be made between the error matrices derived from MSS and aerial photograph interpretation, and between aerial photointerpretation and field data. It is essential that errors identified by the assessment be evaluated to: address the adequacy of differing scales of verification data; identify error sources; separate categorization errors from other errors; and correct the errors, if possible.

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APPENDICES

Appendix I:

NALC Technical Review

NALC Technical Review Session agenda

List of Invited Participants

NALC Review Panel

Report of the Technical Review Panel, North American Landscape Characterization, February, 1993

Comments on the Report

NALC TECHNICAL REVIEW SESSION

JAMES LAWLESS, MODERATOR

Wednesday, February 17, 1993

5:30 pm

OPENING REMARKS

JAMES LAWLESS, NALC PEER REVIEW CHAIR
NASA HEADQUARTERS

6:00

THE "MISSING CARBON" STUDY:
IDENTIFYING GAPS IN AVAILABLE DATA

ALLAN AUCLAIR
SCIENCE AND POLICY ASSOCIATES

6:45

NALC PROGRAM OVERVIEW

ROSS LUNETTA, NALC TECHNICAL DIRECTOR
USEPA, EMSL LAS VEGAS

7:15

NALC USGS/EDC PROGRAM OVERVIEW

JAMES STURDEVANT, USGE/EDC NALC PROGRAM MANAGER
USGS EROS DATA CENTER

8:00

ADJOURN

NALC-PATHFINDER TECHNICAL SESSION

ROSS LUNETTA, MODERATOR

Thursday, February 18, 1993

8:30 AM

NALC OVERVIEW

ROSS LUNETTA, NALC TECHNICAL DIRECTOR,
US EPA, EMSL Las Vegas

9:00

NALC LANDSAT MSS DATA ACQUISITIONS

JAMES LOVE, EOSAT

9:30

NALC DATA PURCHASES
AND PROCESSING PRIORITIES

JOHN LYON, OHIO STATE UNIVERSITY

10:00-10:30

BREAK

10:30

USGS NALC OVERVIEW

JAMES STURDEVANT, EROS DATA CENTER

11:00

IMAGE SELECTION, COMPOSITING AND GEOREFERENCING

JOHN DWYER, EROS DATA CENTER

11:30

IMAGE CATEGORIZATION

JOHN LYON, OHIO STATE UNIVERSITY

NALC TECHNICAL REVIEW SESSION

JAMES LAWLESS, MODERATOR

Wednesday, February 17, 1993

5:30 pm

OPENING REMARKS

JAMES LAWLESS, NALC PEER REVIEW CHAIR
NASA HEADQUARTERS

6:00

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IDENTIFYING GAPS IN AVAILABLE DATA

ALLAN AUCLAIR
SCIENCE AND POLICY ASSOCIATES

6:45

NALC PROGRAM OVERVIEW

ROSS LUNETTA, NALC TECHNICAL DIRECTOR
USEPA, EMSL LAS VEGAS

7:15

NALC USGS/EDC PROGRAM OVERVIEW

JAMES STURDEVANT, USGE/EDC NALC PROGRAM MANAGER
USGS EROS DATA CENTER

8:00

ADJOURN

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ROSS LUNETTA, MODERATOR

Thursday, February 18, 1993

8:30 AM

NALC OVERVIEW

ROSS LUNETTA, NALC TECHNICAL DIRECTOR,
US EPA, EMSL Las Vegas

9:00

NALC LANDSAT MSS DATA ACQUISITIONS

JAMES LOVE, EOSAT

9:30

NALC DATA PURCHASES
AND PROCESSING PRIORITIES

JOHN LYON, OHIO STATE UNIVERSITY

10:00-10:30 BREAK

10:30 USGS NALC OVERVIEW

JAMES STURDEVANT, EROS DATA CENTER

11:00 IMAGE SELECTION, COMPOSITING AND GEOREFERENCING

JOHN DWYER, EROS DATA CENTER

11:30 IMAGE CATEGORIZATION

JOHN LYON, OHIO STATE UNIVERSITY

NALC TECHNICAL REVIEW SESSION

JAMES LAWLESS, MODERATOR

Wednesday, February 17, 1993

5:30 pm

OPENING REMARKS

JAMES LAWLESS, NALC PEER REVIEW CHAIR
NASA HEADQUARTERS

6:00

THE "MISSING CARBON" STUDY:
IDENTIFYING GAPS IN AVAILABLE DATA

ALLAN AUCLAIR
SCIENCE AND POLICY ASSOCIATES

6:45

NALC PROGRAM OVERVIEW

ROSS LUNETTA, NALC TECHNICAL DIRECTOR
USEPA, EMSL LAS VEGAS

7:15

NALC USGS/EDC PROGRAM OVERVIEW

JAMES STURDEVANT, USGE/EDC NALC PROGRAM MANAGER
USGS EROS DATA CENTER

8:00

ADJOURN

NALC-PATHFINDER TECHNICAL SESSION

ROSS LUNETTA, MODERATOR

Thursday, February 18, 1993

8:30 AM

NALC OVERVIEW

ROSS LUNETTA, NALC TECHNICAL DIRECTOR,
US EPA, EMSL Las Vegas

9:00

NALC LANDSAT MSS DATA ACQUISITIONS

JAMES LOVE, EOSAT

9:30

NALC DATA PURCHASES
AND PROCESSING PRIORITIES

JOHN LYON, OHIO STATE UNIVERSITY

10:00-10:30

BREAK

10:30

USGS NALC OVERVIEW

JAMES STURDEVANT, EROS DATA CENTER

11:00

IMAGE SELECTION, COMPOSITING AND GEOREFERENCING

JOHN DWYER, EROS DATA CENTER

11:30

IMAGE CATEGORIZATION

JOHN LYON, OHIO STATE UNIVERSITY

12:00-1:30 LUNCH

1:30 PM DATA MANAGEMENT:
INDEXING, ARCHIVING AND DISTRIBUTION

JOHN DWYER, EROS DATA CENTER

2:00
OVERVIEW OF CHANGE DETECTION

DING YUAN, DESERT RESEARCH INSTITUTE

2:30
ACCURACY ASSESSMENT: QA/QC ISSUES

LYNN FENSTERMAKER, DESERT RESEARCH INSTITUTE

3:00-3:30 BREAK

3:30 METHODS DEMONSTRATION AND PILOT PROJECTS
OVERVIEW

JOHN LYON, OHIO STATE UNIVERSITY

4:00 CHESAPEAKE BAY WATERSHED PILOT PROJECT

DORSEY WORTHY, US EPA, EMSL Las Vegas

4:30
GREAT LAKES WATERSHED PILOT STUDY

BERT GUINDON, CANADA CENTRE FOR REMOTE SENSING
OTTAWA, ONTARIO, CANADA

5:00
STRAWMAN REPORT - CONTENTS/OVERVIEW

REVIEW PANEL MEMBERS

6:00 ADJOURN

NALC TECHNICAL REVIEW SESSION

JAMES LAWLESS, MODERATOR

Friday, February 19, 1993

8:00 AM

REVIEW PANEL REPORT WRITING

JAMES LAWLESS
REVIEW PANEL MEMBERS

10:30

QUESTIONS FOR PARTICIPANTS

REVIEW PANEL MEMBERS

11:30

COMPLETE REVIEW OF DRAFT REPORT

JAMES LAWLESS

1:00

ADJOURN PANEL REVIEW

LIST OF

INVITED PARTICIPANTS

NALC Technical Review, New Orleans

REVIEW PARTICIPANTS

Allan Auclair
Roman Alvarez
Roberto Bonifaz
John Dwyer
Jack Durham
Lynn Fenstermaker
James Love
Ross Lunetta
John Lyon
James Sturdevant
Ridgeway Weerackoon
Ding Yuan
Dorsey Worthy

PEER REVIEWERS

Chuck Dull
John Estes
Leonard Gaydos
James Lawless
Douglas Muchoney
David Peterson
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Report of the
Technical Review Panel

North American Land Characterization Project

February, 1993

Summary

A technical review of the North American Landscape Characterization (NALC) project, an element of the Landsat Pathfinder, was held in New Orleans, Louisiana on February 17-18, 1993. The members of the review panel emphatically and unanimously endorse the goals, objectives and technical approach of the NALC. Specific recommendations are made to improve the utility and scientific merit of the products derived during the course of the project, to assure that the project will meet the information gathering requirements and performance specifications of EPA, and to establish mechanisms for integrating the experience gained, and the data generated by this project into other, large scale, global change research programs.

1.0 Introduction

The North American Landscape Characterization (NALC) project is an excellent example of the type of pathfinder envisioned by the National Aeronautics and Space Administration (NASA). Personnel from the Environmental Protection Agency (EPA), United States Geological Survey (USGS), NASA, Earth Observation Satellite Corporation (EOSAT) and other cooperating organizations have formed a team involved in a scientifically significant, technologically challenging project. NALC is being conducted on a scale that stretches our ability to facilitate science given today's understanding of image acquisition, archiving, data processing, verification and data distribution systems, and it is providing the science community with essential data products. The NALC-Pathfinder's experience is also providing lessons in the creation of large area, multitemporal, high spatial resolution data sets - lessons of great value in the development of EOS-DIS and a variety of global change research efforts. The data sets, archiving, and techniques developed can, and will, make important contributions to resource management not only in the United States and Canada, but Mexico, Central America and the Caribbean as well. The NALC-Pathfinder is important. The project is needed. The review panel supports the effort and believes the program will provide a tremendous benefit to cooperators throughout North America.

The review panel supports, fundamentally, the goals, objectives, and methods of the NALC. As with all reviews, there are areas where the panel members feel improvements can be made. The panel applauds the NALC-Pathfinder's efforts in technique development, and, while comments directed toward specific techniques suggested or recommended by the NALC staff are presented, the comments are intended to call attention to ways in which the final products of the NALC may be improved in an area where continuing research is urgently required.

The goal of the NALC program is to provide scientists with the information they require to conduct global change research. The Pathfinder specifically focuses on the development of techniques and methods which can be applied to the development of standard land cover categorization products in support of global change research efforts of EPA Laboratories in Corvallis, Oregon, and Athens, Georgia. From a science perspective, the Pathfinder seeks to reduce the uncertainty in the area term for carbon stocks and atmospheric trace gas emissions associated with North American land cover type classes. To accomplish this the NALC program will produce hard copy and digital image products from Landsat MSS data suitable to inventory carbon stocks, determine location of carbon sources and sinks and identify areas where the potential exists for carbon sequestration.

The importance of the land cover type categorization of the NALC-Pathfinder should not be underestimated. If we take the equation:

$$A_{(LC1)} + C_{(LC1)} = \text{Total Global Carbon}_{(LC1)}$$

where:

$A_{(LC1)}$ = Area of land cover class 1, and

$C_{(LC1)}$ = Carbon per unit area for land cover class 1,

the reviewers believe strongly that the uncertainty present in the area term of the equation is at least as large, if not larger (and much harder to address,) than the current uncertainty in our knowledge of carbon stock per unit area for given land cover classes. From that perspective, the NALC
project contributes toward meeting the goals of global change science.

Technique development initiated within the scope of the NALC is also significant. There is a need to develop advanced feature extraction procedures for the processing of earth observing satellite data. The NALC is addressing aggressively the issues of categorization, change detection, and quality assurance/quality control (QA/QC) development for large area cover type mapping. The development of a land cover type product, for example, is very much a research area, and any approach taken is subject to criticism.

The review panel received oral presentations on the NALC based on a draft document, the "Landsat Pathfinder Technical Work Plan" prepared by the staff of the EPA's Environmental Monitoring Systems Laboratory. The findings of the review panel are presented in detail below. The organization of this report follows, in general, the organization of the draft document. Specific suggestions and recommendations are made for data acquisition and processing, archiving and analysis techniques, and quality control/quality assurance. Comments are also directed toward project management and the criteria for success. The report concludes with a brief summary and recommendations. This report is a response to the draft document and the material presented during the review. It is not intended as a summary of the NALC.

2.0 Goals and Objectives

The stated goal of the NALC, "...assessing terrestrial biosphere management options as they influence land cover, carbon pools, atmospheric trace gases, and feedbacks to atmospheric conditions...," while broad, is made tractable by the careful selection and prioritization of areas for study that address the uncertainties associated with sources and sinks of carbon in North America. The proposal by the NALC team to address the goal through the use of "triplet" Landsat Multispectral Scanner System (MSS) data sets, is appropriate and probably essential for cost effectiveness. Further, the success of the program is enhanced through the leveraging of the resources of other agencies, universities and the private sector. Compiling the necessary MSS data sets and initiating the effort through pilot study areas to test the working scientific hypotheses and to develop and test methodologies are appropriate objectives. The use of Landsat images from three dates will provide information on the current distribution of the land cover types, rates of change within and among the land cover types, and trends in the rates of change. Such information will be of value not only to EPA and the collaborators in the NALC but to the US Global Change Research Program as a whole. The involvement of cooperators outside the EPA takes advantage of the best skills of the nation and helps assure successful accomplishment of the objectives of the program in a timely and cost effective manner.

3.0 Image Categorization and Development of Land Cover Products

Two key products will provide the bases for the applications - the geographically registered, multi-epoch, multispectral data being assembled at EDC, and the clustered data. NALC is on target to realize the creation of both. Specifically, its proposal to test alternative clustering methodologies and implementations is a good approach. The review panel recommends that these tests be conducted using triplets from representative environments and that measures of success be established. The success criteria might include ability to separate classes of interest, minimization of the border class problem, and ease in labeling.

No categorization technique can be successful without substantial involvement of human interpreters. NALC is correct in stressing techniques that rely on human expertise and judgement in the labeling stage and in trying to minimize the subjectivity that comes with techniques that require selection of training fields, numbers of clusters, etc.

The panel is concerned about the qualifications of the cooperators performing the cluster labeling, and it recommends that the program make sure that the individuals performing that function are adequately trained in multispectral categorization. Supplying the cooperators with measures of inter-cluster separability, divergence and variance is insufficient if the information cannot be used intelligently. Experience indicates that spectral plots are very useful in visualizing the categorization process. In that regard, selection of software that eases class labeling is absolutely essential. It should be possible to highlight classes one at a time, or in groups, with easily selected color codes. Systems that allow viewing of the multispectral data while labeling are especially helpful.

The selection of a categorization system is obviously important and difficult. While the proposed system appears to be one that is achievable with Landsat MSS data, it does not seem to be "ecologically oriented" as presented. Since measurement of closed forest canopy and its change with respect to clearing and regrowth is critical to the Global Change Research Program, a closed forest class should be included. There also appears to be a gap with respect to savanna or scrub/shrub categories. Since NALC data can be interpreted in concert with ancillary data, more consideration should be given to how such additional information can aid in the categorization or refinement. There is also the problem of clear definition and procedure. How is an important phenomenon like forest regrowth handled? Is a patch that has just been cleared "barren," or is it "herbaceous?" Due to seasonality inherent in the data, such a cleared patch may appear barren one month, herbaceous the next. At which stage does it get classified as woody? In an evergreen forest (as in the Pacific Northwest), does the regrowth start out "deciduous" or "mixed?" These stages, and how they are handled in the categorization, are important to consider carefully because maps and statistics on land cover change will result from a coarse temporal sampling of the data over 20 years. Much work needs to be done, prior to actual labeling, in categorization, standardization, description of and developing application protocols, and in documenting clear guidelines for cooperators to apply to the categorization system. The present categorization system would benefit from additional review and testing. In particular, a review of results of other categorizations applied to MSS data and like techniques is needed. There are robust examples from which to choose.

Strong consideration should be given to preparation of several categorizations for specific science users. Though science users of NALC have been consulted with regard to the categorization system, it may be feasible to achieve finer categorizations for specific objectives (like tracking forest regrowth or burns) if multiple categorizations was offered.

The NALC is creating a data base of wide applicability. In addition to the specific land cover type and land cover change products that will emerge from the NALC to meet the science and operational requirements of EPA, the variety of other potential products is quite large. These products may include various image enhancements to expedite photo interpretation or image mosaicking, vegetation indices, categorizations optimized for specific purposes (such as identifying stages of forest regrowth), or categorizations mapping different classes than those proposed by NALC. Furthermore, a variety of measurements related to patch shape and size, as well as spatial autocorrelation, may be calculated based on either the multispectral or categorized data. Combining NALC data with other sources, such as AVHRR time-series, TM, SPOT, or even digital orthophotos, may also prove valuable.

The ability to use NALC data in a geographic information system (GIS) is quite promising, both for enhancing the ability to achieve desired categorizations, and as a way of quantifying measures over specific areas (such as forest districts) or in association with other factors (such as steep slopes). While these may be beyond the needs or ability of the NALC program or EPA at present, it should be noted that the program will provide a solid foundation for others to work from.

4.0 Methods for Managing and Distribution of NALC Data

4.1 MSS Data Processing

Preprocessing of MSS data ceased at the Norman OK ground station after September 19, 1992. It is uncertain that all MSS scenes acquired in 1992 during the acquisition window were pre-processed prior to the failure. It is also uncertain if (and when) EOSAT will bring the capability for MSS pre-processing back on-line, and/or if any of the foreign ground stations retain the capability. Given the current status of MSS pre-processing, and the ongoing effort by EPA to bring the Canadians in to the NALC project as a scientific collaborator, EPA is encouraged to inquire of CCRS:

1. the extent of MSS coverage of Canada for 91-92
2. if the Canadian Ground Station at Prince Albert has maintained the capability to pre-process MSS data, and
3. if the HDT's from Norman can be pre-processed by CCRS.

EPA is encouraged to determine, as soon as possible, if all MSS data required for NALC has been acquired and pre-processed, and to make any unfulfilled needs for MSS data acquisition or pre-processing known to the Landsat program managers at NASA HQ.

4.2 Triplet Processing

Current output of triplets at EDC is about one every 1.5 days on a multi-tasking system. Although the rate of data processing may be adequate to meet the applications schedule as described, increasing the throughput rate would be advantageous as it would allow for pilot testing and technique evaluation sooner and in a broader ranger of environments.

4.3 IMS

Procedures for comprehensive collection of ancillary meta-data describing the images has been put in place by EDC and is ready for placing these data in an Information Management System. The panel recommends that the IMS is implemented as soon as possible and that it is not treated as a retrospective exercise after image preprocessing is complete.

The project would benefit now from the availability of an operational IMS so that the progress of the project in developing triplets with know characteristics can be assessed comprehensively. In the absence of an IMS, project management, currently, has to rely on overly qualitative assessments of many important image characteristics.

The experience of the Landsat Pathfinder in the humid tropics in the construction of an IMS should be used to help guide the development of the NALC-Pathfinder IMS.

4.4 Data Standards

Compilation of land cover and land cover change standard products to repopulate the data archive must be closely monitored and analyzed with the cooperation of the appropriate land management organization. Standards for the data products must also be developed in close coordination with the Federal Geographic Data Committee.

4.5 Field Inventory/Field Data Management

Field inventory should include the consistent and proper use of appropriate field forms and data collection and management techniques. A plan for management of field data information should be developed and implemented. Sources of guidance for field inventory and field information management are the US Forest Service and The Nature Conservancy.

4.6 Sampling Allocation/Sampling Frame Development

Field verification methods have been developed by the NALC-Pathfinder, but methods for guiding field evaluations for cluster labeling activities have been neglected. Even when analysts with knowledge of local conditions are available, labeling benefits from field work. A sampling frame based on cluster categories should be developed and field sites selected so as to maximize observations along gradients. Sampling should be nominally proportional to class or strata area while keeping potential access restrictions in mind. Collection of verification data should be made concurrently.

4.7 Ancillary Data - Biotic Community

Biotic community categories and scales need to be defined to evaluate their utility. The most appropriate use of this type of data needs to be defined. Biotic community data may be useful, but research needs to be performed on data availability and integration techniques.

5.0 Change Detection Methodology

The panel agrees strongly that change detection is an important activity that can aid in the characterization and monitoring of land cover. Retrospective change detection provides timely estimates on the extent and type of change as a prelude to monitoring. The panel's recommendation to refine the change detection methods primarily address technique, rather than program. Specific areas of concern are multitemporal radiometric normalization, atmospheric correction, change detection techniques, test site activities, and most importantly, reconciling program objectives with change detection methods and change categories.

The science requirements of NALC for change detection information have not been developed and/or reported. The objectives of change detection are not clearly developed. Change categories have not been defined and reconciled with the land cover categorization scheme. In addition, the means of incorporating change detection information into categorization, categorization, stratification and sampling frame development and verification need to be further developed.

It is not apparent that change detection techniques, applications and results have been researched fully. The categorization of change detection techniques presented to the reviewers may not be appropriate. It does not convey balanced information on categories of techniques.

Generally accepted categories of change detection techniques are:

- Spectral-temporal change detection (layered-temporal)
- Principal components analysis
- Image differencing (image ratioing inclusive)
- Post-categorization change detection differencing

Vegetation index differencing (VID), the technique selected by NALC, is most appropriately a sub-group of image differencing or post categorization change set-differencing since derived, single data categorizations (VI) are subtracted on a pixel-by-pixel basis. At best, VID belongs at the same level as the other categories.

Change detection method development in NALC has not been adequately undertaken (or documented). VID was apparently chosen prior to testing. It has several serious flaws and other techniques should have been included in testing and analysis.

One problem with VID is the possibility that a number of land cover types, given their natural variability and high level of abstraction as classes, will map across virtually the entire range of VIs. This can be the result of either ecological factors which vary across the landscape and control biotic parameters, e.g. leaf area development, or seasonal variation in the leaf development of many communities as varied as "deciduous" or "cultivated land, or both. VI, therefore, may have difficulty distinguishing corn fields from deciduous forest - a potential confusion between land cover types of some significance.

The need and methods for performing multitemporal equalization (normalization) and atmospheric corrections are in question. There are techniques such as principal components analysis (PCA or Karhunen-Loeve Transformation) which obviate normalization and provide useful information on sensor calibration and atmospheric effects. Image differencing would characterize the per-band distribution of inter-image change, thereby providing information on change due to factors other than object (feature).

VIs are particularly sensitive to variations in atmospheric conditions. These indices are typically based on the contrasting biological influences on the near-infrared versus red reflectance patterns (scattering versus absorption, respectively). Given Rayleigh and Mei scattering effects, particularly strong in the visible (red), the atmospheric effects are manifested largely through the red band (denominator). No VI can correct for atmospheric effects since they are additive not multiplicative. The project should carefully re-consider the atmospheric correction issue.

It is recommended that extensive testing of change detection techniques be performed at each of the pilot sites - especially in areas where prior research data are available such as the Virginia Coast Reserve LTER which is within the Chesapeake Bay Pilot area.

The panel recommends that NALC cooperate with the larger technical science community, including experts at EDC, for evaluation and development of change detection techniques and methods. Change detection would be significantly helped by determining, with the aid of the scientific community, which land cover transitions are most important and which have little impact on the scientific objectives. This should lead to substantial simplification of this part of NALC.

There is also a need to look at the effect of the long temporal windows anticipated for some areas. Because of cloud cover, triplets will be created using data obtained at different times in the growing season. The inevitable variation in phenology and vegetation condition may make characterization of condition difficult and obscure changes in land cover. Efforts should be directed toward developing techniques that address these anticipated problems.

There should also be a closer tie with the GCRP program scientists to ensure that change detection products meet their specific, scientific goals.

6.0 NALC Management, Scheduling and Coordination

Based upon discussions at the management overview and presentation by Allan Auclair, it appears that the primary focus of NALC should address and identify fluctuations in and to better understand the carbon flux in the temperate/boreal forest. Preliminary conclusions suggest the temperate/boreal forest are not at climatic equilibrium or at carbon steady-state and appear to drive the net biospheric flux of the carbon cycle. Suggested research and policy applications included further action to acquire and verify data on forest depletions and inventory available databases. Therefore the development of a terrestrial carbon monitoring system to track sinks, sources and net carbon budget annually, with subsequent development of criteria to regulate terrestrial biospheric carbon fluxes, is predicated upon change detection analysis, specifically forest change detection and monitoring.

The NALC-Pathfinder primary objectives include; acquisition of current observations for North America to complement existing historical data sets; to provide easy access and integration with past, present, and future data sets; and derive land cover change output products using standardized data sets and standardized methods. Close coordination with major land management organization will be required to implement these objectives most effectively.

The NALC-pathfinder program has the potential to provide a wealth of needed information to land management agencies such as the USDA Forest Service, BLM, National Park Service, TVA, state agencies and private individual land managers. Their cooperation and participation will be instrumental, if not absolutely essential, in the development of reliable and credible outputs for the NALC-Pathfinder program in support of global change programs. Use of existing databases established by the organizations will be necessary to support and validate output products. These organizations also comprise the primary users, or clients, the program will support. Proposed benefits of the NALC-Pathfinder program must be coincident with the data needs of these organization to ensure the success of this interagency, cooperative program.

The EPA, USDA, NASA, & DOI have already contributed substantial efforts to support the USGCRP. Data acquisitions and production of co registered MSS triplets will provide a national archive of tremendous utility and importance to the global change research community. However, the data base must also address the needs, and meet the requirements, of those agencies having legislative authority to affect the change necessary to "regulate" terrestrial biospheric carbon fluxes.

Data acquisition and assembly of MSS triplets is a substantial task which will continue to require close cooperation between EPA, NASA, EOSAT, and EDC. Production of the land cover and land cover change products is a major task requiring substantial cooperation between the aforementioned land management organizations. Other agencies such as ASCS, SCS, F&WS, FAS and international forestry and conservation organizations (to name a few) should support, and receive benefit from, this program. Standard algorithms and methods manuals should be provided to these organizations along with the MSS triplets and appropriate technical and financial support.

Given the complexities of interagency, interdisciplinary organizations, the NALC is being managed with a high degree of success. The project has faced significant logistical and research tasks that have necessitated a flexible, innovative approach in project management. This quality was well demonstrated in the review by the effective way task managers responded to questions from the review panel.

An area where strengthening of the management structure would be beneficial is in closer coordination between EPA scientists, for whom the data sets are being created, and the remainder of the project. For example, representatives of this community participate in the NALC Science Working Group, but closer involvement in the development of technical aspects of the project, possibly through the NALC-Pathfinder Technical Work Group, is desirable. Closer involvement is required so that the technical development of the project can respond to improved specification of scientific requirements and to revised scientific priorities. Specifically, the review panel recommends that the NALC-Pathfinder Technical Working Group is expanded to include representatives of EPA and other global change science groups.

It is expected that it will be necessary for the Technical Work Group to maintain a relatively high frequency of meetings to manage the large range of technical developments anticipated in the work plan of NALC-Pathfinder.

The review panel also recommends that those responsible in NASA and other agencies for the overall management of Pathfinder projects develop active mechanisms to compile and analyze the experience of NALC-Pathfinder, and other Pathfinder projects, so that EOS-DIS will benefit from the Pathfinder activities. One possible mechanism might be to create an overall Pathfinder Science Committee containing agency managers, chairs of the individual science teams and managers of the pathfinder projects.

Another area where the input of the EPA science community is especially desirable at present is in the sequence of areas to be analyzed by the project. It would appear that by modifying the order in which different regions are analyzed, a more timely response to scientific priorities could be achieved. For example, an earlier analysis of the Pacific Northwest than that currently planned, would seem to be needed. Also, the order in which areas are analyzed for testing and development of methodology should be reconsidered so that a wider range of environments is examined than those currently proposed. It is therefore recommended that a review of the sequence of data processing and analysis be implemented.

7.0 Quality Assurance and Quality Control

QA/QC in the NALC is in the developmental stage. The review panel is pleased to see that this topic is being addressed and that NALC participants are researching cost efficient methods for implementing QA/QC procedures in all aspects of the Pathfinder. One major success criteria, the attainment of the 85%/85% goal (85% correct/85% of the time) for categorization accuracy can only be achieved if innovative statistical spatial sampling procedures are implemented. Other QA/QC activities, while challenging, are somewhat more straight forward (e.g. cloud cover estimation, RMS, geometric registration verification.)

The purpose of the quality assessment (particularly the accuracy assessment) effort is uncertain, both as to its intended uses and its motivation. Since such efforts can be very costly and time consuming, the effort should be designed to provide more than a "figure of merit" such as class-by-class categorization accuracy. This depends on whether, for example, its motivation is to improve area proportion estimates or to provide "hard" data for improved spatial mapping using the "soft" remote sensing data (e.g., spatial statistics or geostatistical uses.) The latter motivation would imply a design which avoids introducing too much bias into the accuracy assessment sample through use of multistage sampling techniques. To the degree this is done, and the assessment data are preserved, the continued re-use of these data by the broader scientific community will be assured.

The panel believes that a good start has been made, but more still needs to be done. The choice of 85%/85% seems to be arbitrary and the consequences of failing to meet it should be developed from a science perspective. Examination of spatial sampling that have been accomplished in projects such as those done by the United States Geological Survey, and the University of California Santa Barbara, need to be examined. Several panel members feel that the project should look at a stratified, systematic, unaligned sampling strategy with double sampling to, as best as practical, cover under-represented categories. In addition to the procedures discussed, the panel believes that Pathfinder project personnel should consider the use of independent analyst interpreter verification of the accuracy of sample locations directly from the MSS imagery employed in the categorization process. Done with proper care and diligence, this should not introduce significant bias into the verification process, and studies have shown it to be an effective and efficient method of accuracy verification.

Use of qualified interpreters analyzing the MSS data does not necessarily rule out the use of local expertise but can make such use more effective and cost efficient by focusing attention on categories that are more difficult to verify.

The panel questions whether the data form categories proposed are realistic using photointerpretation when land cover goals are more modest. The use of photointerpretation as a basis for accuracy assessment may be fraught with logistical difficulties. In addition, the goals described in the intended interpretation data form may be unrealistic, e.g., species types. The procedure is probably sufficient for the limited purposes of the categorization scheme.

The panel recommends that efforts continue on the development of cost-effective, large-area categorization verification sampling procedures. It also recommends that the panel, or some other independent review board, review the procedures developed prior to implementation.

8.0 Global Change Science and Methodology

To achieve a balance between meeting global change science goals and meeting the technical goals of NALC, the program must strike a reasonable balance between the diverse needs of a changing scientific customer base and the desire to standardize procedures. Land cover type and change in land cover, features of the landscape resolvable with Landsat MSS, have been established as the data needs by NALC's primary customers - the studies being conducted at the Corvallis and Athens EPA labs on carbon cycle questions. The NALC team should continue to work with these two EPA labs to arrive at an appropriate and translatable scheme for categorizing the data set into land cover type classes. This cooperation is the basis for the scientific value of tracing a 20-year change in land cover for North America. Once it has addressed the needs of its primary customers, the data set developed by the NALC will be suitable for applications pilot projects throughout North America. The pilots projects will help maintain the balance between science and technical objectives by evaluating the trade-offs between desired information and its dependence on particular techniques.

9.0 Measures of Success

Listed below are four criteria for success that the review panel members believe represent the goals and objectives of the NALC program:

1. Provide data, currently unavailable, to drive existing EPA land processes models, which, in turn, will help formulate agency policy decisions.
2. Compilation of a well designed standardized set of data products, including wall-to-wall triplet raw MSS and ancillary data, land cover images and statistics, tabular data, and evaluation of land cover change. This data set is designed for, and must be made readily available (as evaluated by physical access and cost) to the science and application user community. As such, it will have the very real potential of providing return on investment will beyond anything currently envisioned. The degree to which the data base is acquired and used in meaningful scientific investigations will measure how well this is accomplished.
3. Scientific and technical publications in the peer reviewed literature.
4. Concrete examples of how high spatial resolution (MSS) data improve our understanding of land cover change and its effects on global change phenomena versus other approaches, e.g. point data, traditional mapped data, and coarse resolution data.

10.0 Conclusions and Recommendations

The NALC is truly a "pathfinder." It is developing a data base and an operational use for remotely sensed data that will meet the needs of EPA and that will serve as a model for other global change research efforts. The review panel concurs with the goals, objectives and approach of the program, and presents the following recommendations to improve the efficiency of the data processing and the robustness of the results.

10.1 General Considerations

• The direct links between specific science questions on carbon cycles and the information needed to solve them, or improve EPA's understanding with the NALC technical approach and goals, need more clarity and definition.

• The purpose of some activities, e.g., accuracy assessment, is unclear and difficult to tie to specific science goals.

• The scientific arguments as to why the specific land cover categorization scheme will or will not satisfy important gaps in understanding and predicting carbon cycle questions are not sufficiently made and need better definition.

• The relationship between the schedule for data delivery and the applications projects with major scientific uncertainties suffers from the lack of a clear scientific rationale.

• NALC's efforts are a key driving force in the overall Landsat Pathfinder program. As such, the potential customer or user base is likely much larger even within EPA than the current EPA base. The NALC management clearly recognizes this and has been motivated to remain sensitive to potential changing information needs by seeking to standardize products, to retain useful analyses, such as clustering, at levels that permit reinterpretations, and by seeking to retain accuracy assessment data together with the Landsat data, all archived at the EROS Data Center. The team is attempting to define an information management systems for the NALC data base that will allow access to the greater scientific community. EPA should proceed with caution, once the NALC technical procedures are set, in deviating significantly from their path if needed or requested by other science users. Different users may want to alter the priorities on scheduling. This should be weighed, with caution, against the need to complete the wall-to-wall, 3-epoch data set and the needs of NALC's original EPA Global Change customer base. EPA could avail itself, as NALC has already begun to do, of collaborative opportunities for "application projects" so as to leverage their significant NALC effort.

• NASA, and the other agencies participating in the Pathfinder Program, should develop mechanisms to assimilate the NALC-Pathfinder experience, and that of other Pathfinder projects, in the development of EOS-DIS.

• One area, where the input of the EPA science community is especially desirable at present is in the sequence of areas to be analyzed by the project. It would appear that by modifying the order in which different regions are analyzed, a more timely response to scientific priorities could be achieved. For example an earlier analysis of the

Pacific Northwest, than that currently planned, would seem to be needed.

• The NALC should specify criteria for success so that the progress and accomplishments of the project are readily apparent.

10.2 Technical Recommendations

- Categorization:
  1. Measures of success should be established for testing categorization techniques, e.g. ability to recognize categories of interest, ease of labeling, etc.
  2. Categorization tests should be conducted using triplets from representative environments.
  3. Alternative categorization techniques should be tested before a categorization methodology is chosen for the duration of the program.
- Labeling of categorized pixels is crucial to the success of the program. The individuals performing the labeling must be trained adequately in multispectral categorization techniques.
- Immediate implementation of an IMS will greatly improve the efficiency of the program and its chances to meet all its objectives.
- Increasing throughput of compilation of the triplets would allow for pilot testing and technique evaluation sooner and in a broader range of environments.
- Efforts should be taken immediately to assure all required MSS scenes were collected and preprocessed, or that a mechanism exists to complete the preprocessing.
- Compilation of land cover and land cover change standard products should be monitored and analyzed with the cooperation of the appropriate land management organizations
- Field inventories should include the consistent and proper use of field forms and data collection and management techniques.
- A sampling frame approach for cluster labeling activities should be developed and implemented.
- Change detection methodology:
  1. Evaluation of alternative change detection methods should be performed. The cooperation of the appropriate elements of the science community should be sought for that effort.

2. Extensive testing of change detection techniques should be performed at each of the pilot sites.
3. Explicit procedures for change detection given the temporal variation in the triplets should be developed and evaluated.

- Membership in the NALC-Pathfinder Technical Working Group should include the science community within EPA and other research programs directed toward global change.
- QA/QC needs to be fully developed and evaluated. A rationale for the selection of the "85/85" criterion should be developed based on science requirements. Evaluation of other QA/QC should be attempted.
- Efforts should continue toward the development of cost-effective categorization verification sampling procedures. The procedures must be reviewed prior to implementation.

Panel Review Members

Dr. Chuck Dull	US Forest Service Washington, D.C.
Dr. John Estes	Dept. of Geography University of California, Santa Barbara
Dr. Leonard Gaydos	USGS, Ames Research Center Moffett Field, California
Dr. James G. Lawless (Chair)	NASA Headquarters Washington, D.C.
Mr. Douglass Muchoney	The Nature Conservancy Arlington, Virginia
Mr. David Peterson	NASA Ames Research Center Moffett Field, California
Mr. Edwin Sheffner	TGS Technology Ames Research Center
Dr. David Skole	CSRC/EOS University of New Hampshire, Durham, N.H.
Dr. John Townshend	Dept. of Geography University of Maryland, College Park, MD.

NORTH AMERICAN LANDSCAPE CHARACTERIZATION (NALC) PROJECT

RESPONSE TO THE NALC PANEL REVIEW REPORT

The organization of this response follows the format provided in the NALC Panel Review report. The order is patterned after the format of the NALC Technical Work Plan and order of presentations at the NALC Technical Review session in New Orleans.

The responses to comments by the Technical Review Panel specifically address those areas identified as requiring additional attention. The objectives of the responses are to identify how we intend to act upon the comments.

3.0 IMAGE CATEGORIZATION AND DEVELOPMENT OF LAND COVER PRODUCTS

In response to comments in this section of the Panel Report, we intend to develop measures of success, establish them programmatically, and characterize the methods to evaluate them as to their appropriateness. These issues include addressing the separation of classes, the border class problem, and methods to ease the labor involved in labeling.

It is desirable to devote further attention to the qualifications of associated researchers as related to capabilities in computer categorization and labelling of classes resulting from analysis of Landsat data. This will help assure their performance and adherence to standard procedures. We will assist them, by developing routines which supply spectral plots and which will highlight individual classes to further assure high quality work in labeling land cover classes. Attention will be devoted to better describing the classification system classes, including closed forest and savanna or shrub/scrub classes. We will address and clarify methods to handle the question of land cover condition or type following harvest.

Further efforts will examine the use of ancillary data along with NALC products, such as AVHRR time series, TM, SPOT and/or digital orthophoto data. These efforts will be conducted directly to insure their characterization early on.

These efforts will also entail further review of literature as to previous results, levels of accuracy achieved, and further documentation on background of the criteria selected for the NALC Project.

4.0 METHODS FOR MANAGING AND DISTRIBUTION OF NALC DATA

In 1992 over five hundred and sixty MSS scenes were acquired by EOSAT and pre-processed in support of the project. These scenes along with those in the archive are being identified and scheduled for triplicate production. To augment this source, EPA and USGS are in contact with the Canada Centre for Remote Sensing. The goal is to determine the extent of 1990/91/92 MSS data that have been acquired from Canadian sources, and that can be used for NALC. We will also determine their capabilities to pre-process EOSAT HDT-R products using their HDT-A processing stream.

As part of these efforts we will evaluate options to increase the throughput of MSS scenes through the processing procedures by the EROS Data Center.

The NALC Information Management System (IMS) is currently being implemented. The characteristics will be evaluated with a perspective of serving the needs of production level data and metadata management, and later requirements important to public access and browsing. Work has been conducted to learn from the experience of the IMS of Landsat Pathfinder on the Humid Tropics (HTRIP), and see how this Arc/Info based approach may be of assistance.

Data processing standards will be further coordinated with interested federal agencies. This will take the form of further consultations, and inclusion of additional personnel in the Technical Work Group.

Field and aerial photo sampling techniques and data record sheet will be further developed. This will be accomplished with an eye toward assisting in the field/laboratory labeling of categorized images, and towards the capture of a variety of land cover conditions during field studies.

5.0 CHANGE DETECTION METHODOLOGY

The approach to detection of change in land covers will be refined following the comments provided by the Panel. This effort will include evaluating other change detection approaches, such as principal components analysis, regression-Chi square analysis, image difference methods, and post-classification change detection methods. The methods and approach will be evaluated on a variety of sites representing the variability in land covers to be encountered during the Project. The determination of methods to be used will be made with a focus on the final products and science issues related to detection of change.

In particular, we will focus on relating change detection methods to identifying land cover changes important to the science objectives, and insure there is a fully reconciled land cover classification system for change detection. This effort will be conducted in cooperation with the science clients within the Agency and others. This effort will involve additional, exhaustive evaluations of available methods. This work will be conducted with the assistance of researchers actively involved in applications. The experience of governmental, industrial and academic personnel will be tapped.

The issues of image pre-processing with regard to systematic corrections and other radiometric corrections will be re-visited. Issues will include atmospheric corrections, sun angle corrections, and the long temporal windows encountered in analysis of some scenes.

6.0 NALC MANAGEMENT, SCHEDULING AND COORDINATION

Further cooperation will be fostered with Agency science clients and with other land management agencies that have an opportunity to respond to the results through modification in management practices. Cooperation with the USGS, DOI agencies, USDA agencies, TVA and others is envisioned. It is anticipated that vehicle for such cooperation will be meetings with interested parties and membership on the Technical Work Group.

An additional goal of this cooperation will be to identify existing databases held by these groups. Use of such ancillary data may be of great value to the work of NALC, and its scientific clients.

It is also necessary to further develop the links with the Agency science clients. It is anticipated that attendance of more clients at the Technical Work Group sessions would assist this process. Further visits to Agency Laboratories, as a follow on to previous visits, will also help to further appraise clients of opportunities, project progress, and allow feedback on requirements related to scientific objectives.

Stronger links will be forged with the image processing and image application communities. The Project can use their input to assure high quality results and assure acceptable standard methods for data processing. This effort is on-going with the advent of talks on the Project presented to university audiences, non-profit and industrial groups, and additional federal audiences. Linkages have been developed to date with Agency scientist including EMAP personnel, USGS Center for Inter-American Mineral Resource Investigations (CIMRI) scientists, USGS Water Division scientists, USFWS Gap Project personnel and others.

7.0 QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

The need for quality assurance procedures and quality control mechanisms is mandated by Agency policy. It is an important aspect of the Project due to the high level of interest in accuracy assessments, and methods are also an important result of the work.

The QA/QC plan is being further developed to track the production and document the quality of triplicate products. The quality goals have established based on Agency policies and the work is on-going. The procedures are currently being reviewed to determine their adequacy.

The determination as the categorization accuracy is an important Agency QA/QC goal. It is also important to the user community and to the Technical Review Panel. We are currently developing the protocol to be applied. Recommendations from the Panel such as reconciliation of science objectives and accuracy assessment objectives are being implemented. We are also re-evaluating the categorization accuracy quality objectives to further ground them in scientific experience.

The land categorization methods and survey sampling methods to accomplish the accuracy assessment are undergoing further study and exhaustive documentation. This effort will be thoroughly grounded in theory and literature, and draw upon experience in the government and in other research arenas. The approaches of stratified systematic sampling, and double sampling will be further evaluated. Methods for systematic sampling in general require further attention, as does the level of effort devoted to each MSS scene, and the use of a combination of photo interpretation and ground sampling methods.

Further attention will be devoted to developing photo interpretation sheets for accuracy assessments. The issue of independent photo interpretive assessment of accuracy will be addressed. Photo interpretive keys will be developed to guide the interpreters in their assessments. The photo interpretative keys will also be optimized recognize the difference in detail between photos and the land cover categories.

The Panel will have the opportunity to review these procedures during the next Technical Work Group meeting in May 1993 and in the next draft of the Technical Work Plan appearing at about the same time.

8.0 GLOBAL CHANGE SCIENCE AND METHODOLOGY

In additional to the comments addressed above, the Project will develop procedures to further communicate the elements of the work and further the dialogue between the user community and NALC personnel.

9.0 MEASURES OF SUCCESS

The measures of success articulated in the Technical Panel Report are particularly clear, and germane to the effort. These measures include: NALC products and results will augment EPA inventory and modeling efforts; the standard NALC products will be a valuable resource for the general scientific community; the characteristics of products and result of NALC will be disseminated in the peer reviewed literature; and the results will demonstrate the value of area-based sampling as compared to traditional sampling approaches alone.

10.0 CONCLUSIONS AND RECOMMENDATIONS

As addressed previously, the NALC Project will continue to refine the link between the specific scientific questions that drive the Project and the technical approaches and goals.

Appendix II:

Agreement Between INEGI and USEPA

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL MONITORING SYSTEMS LABORATORY-LAS VEGAS
P.O. BOX 93478
LAS VEGAS, NEVADA 89193-3478
(702/798-2100 - FTS 545-2100)

MAR 24 1993

Nestor Duch Gary
Director de Geographia
Instituto Nacional de Estadistica, Geografia e Informatica
Heroe de Nacozari No. 2301
Puerto 7 Anexo
C.P. 20290 CD, Industrial
Aguascalientes, Mexico

Dear Mr. Duch:

The Office of Research and Development of the U.S. Environmental Protection Agency has undertaken a project known as the North American Landscape Characterization (NALC) as part of its Global Change Research Program. The objective of this project is to produce land cover and land cover change datasets for use in the inventory of terrestrial carbon stocks and for estimating the flux of carbon which has occurred due to land cover change. Project areas include Central America, Mexico, Caribbean Islands, and the U.S.A.

The NALC land cover and land cover change data sets are to be derived from Landsat MSS "triplicates" which are currently being assembled for the project areas by the U.S. Geological Survey, EROS Data Center (EDC). The triplicates consist of three dates of georeferenced Landsat MSS data, with scenes from the early 1970's, mid-1980's, and early 1990's. Where available we are also adding digital terrain model (DTM) data and digital ecoregion or biotic community data sets. To cover all of Mexico will require the assembly and analysis of 99 of these triplicates.

Our primary collaborator in the U.S.A. is the EROS Data Center. This is a very natural collaboration for several reasons. EDC is an operational arm of the USGS National Mapping Division, which has responsibility for coordinating national mapping projects and producing national map products. In addition, the federal archive of Landsat MSS data resides with EDC.

The Data Center is assembling the NALC triplicates in support of the NALC project. The topographic maps and digital terrain datasets for the USA triplicates are being provided by EDC as one of their contributions to the project. EDC will establish an open archive for the NALC datasets, which will be available to the wider scientific community. While the specific details on distribution media and costs are still to be worked out, the intent is that the NALC datasets will be distributed by EDC at the marginal cost of filling individual orders.

Our relationship with the EROS Data Center is very productive and represents a long term commitment of EPA and USGS to work together in producing high quality land cover and land cover change datasets. We would like to establish a similar relationship with the Instituto Nacional de Estadistica Geografia e Informatica (INEGI). This is in recognition of the special role INEGI plays in producing and distributing geographic datasets for Mexico. As the Technical Director of the NALC project, I am able to commit to the following terms of agreement, which can be the basis for am expanding collaboration between the EPA's Environmental Monitoring Systems Laboratory - Las Vegas (EMSL-LV) and INEGI. All data distribution commitments by EMSL-LV are subject to the availability of NALC project funds.

DATA EXCHANGE:

1) EMSL-LV will provide a complete set of the georeferenced Landsat MSS triplicates and ancillary data sets to INEGI in digital form.

2) INEGI will provide the topographic maps and digital terrain model data sets required for the assembly of the Landsat MSS triplicates for Mexico.

3) The objective of the NALC is to derive land cover and land cover change datasets for large portions of North America. EPA will invite INEGI participation in the analysis of the Mexican data sets. Particular attention will be paid to producing output products which are compatible with existing INEGI land cover maps for Mexico.

4) INEGI is free to use the NALC data sets they receive for other projects.

DATA DISTRIBUTION:

1) No copyright or trade secret restrictions will constrict the distribution of the NALC Landsat data sets. Any holder of those data sets may utilize, copy, and distribute those data sets. At INEGI's request, restrictions will be placed on the distribution of INEGI provided DTM data sets of Mexico.

2) The central archive and distribution center for the NALC project is the USGS EROS Data Center. In determining a price for the data sets, EDC plans to simply recover the costs associated with filling a specific request.

3) EMSL-LV invites INEGI to become an archive and distribution center for NALC data sets of Mexico. INEGI is free to set their own pricing and distribution system.

TERMS FOR USE OF THE DTM DATA:

The DTM data will be coregistered to the Landsat MSS scenes and these combined data sets will be archived and distributed from EROS Data Center. Based on our agreement with EDC terms set by INEGI for the distribution of the Mexican DTM data sets will be respected. In working with EDC on this issue it would be possible to restrict access of the Mexican DTM data sets to non-commercial applications. This would involve the submission of signed statements from any organization requesting the data sets, attesting to their non-commercial status and non-commercial applications for the DTM data of Mexico.

Sincerely,

Ross S. Lunetta

Ross S. Lunetta
NALC - Technical Director

Instituto Nacional de Estadística,
Geografía e Informática

DIRECCION GENERAL DE GEOGRAFIA

A.93.72.082

April 5, 1993

Mr. Ross S. Lunetta
Technical Director - NALC
U.S. Environmental Protection Agency
Environmental Monitoring Systems Laboratory
944 E. Harmon Street
Las Vegas, Nevada 89193
U.S.A.

Dear Mr. Lunetta,

Thank you for your letter of March 23, 1993 regarding the EPA-USGS North American Landscape Characterization (NALC), which is a component of the U.S. Global Change Research Program. In your letter you have proposed an exchange of data, with INEGI providing map and digital elevation data for use in producing the basic NALC data sets for Mexico. In addition, you have invited the participation of INEGI in the conduct of the NALC project in Mexico.

In recognition of the scientific merit of the NALC project and its close match to several of INEGI's technical objectives for the 1990's, I am pleased to inform you that INEGI agrees to the data exchange outlined in your letter.

Specifically, INEGI agrees to provide:

1) The digital terrain models (DTMs) for all of Mexico. Please note that these data sets are being provided for non-commercial use only, under terms described later in this letter agreement.

2) Topographic maps at 1:50,000 and 1:250,000 scales for all of Mexico.

3) Land use / land cover maps of Mexico at 1:250,000 scale.

4) Selected aerial photographic prints of Mexico from existing archives held by INEGI.

The data sets to be provided to INEGI by EPA include:

1) The NALC Landsat MSS data sets of Mexico for three time periods (1970's, 1980's, and 1990's) in the form of georeferenced and coregistered triplicates.

2) The DTM data for the Mexican MSS triplicates, resampled to the MSS spatial resolution and clipped to the MSS scene coverages.

3) The digital land cover and land cover change data sets produced through the analysis of the NALC triplicates of Mexico.

Regarding the DTM data, INEGI is providing these data sets for use in the scientific research to be conducted with the NALC data sets. In order to preserve the commercial markets that INEGI has established for these data sets, we request that the EPA and USGS restrict the access of these data sets to government entities, universities, and non-profit organization. We request that the users of the DTM data sign agreements binding their use[B of the data to non-commercial projects and preventing the unauthorized dispersion of the data. Attached for your consideration are draft copies of the style of application and agreement which we would like to have executed by each group receiving the Mexican DTM data. It is our understanding that the USGS EROS Data Center has agreed to administer this application and agreement system and that INEGI will be provided with copies of the completed forms on a periodic basis.

INEGI intends to maintain an archive of the NALC data sets, which will be used for our internal projects. We expect to also establish a system for distributing these data sets to government entities and scientific investigators in Mexico, in response to data requests. We recognize that these data sets will also be available from the USGS EROS Data Center.

INEGI is the principal agency in Mexico responsible for the production, maintenance, and distribution of cartographic and spatial data sets. As such, we are pleased to accept your invitation for INEGI participation in the NALC project for Mexico. I believe that INEGI's participation will make a valuable contribution to the NALC project. Please keep us informed of the meetings, reviews, and other activities for the NALC project so that our staff has an opportunity to attend.

At the present time our staff has commenced the assembly of the topographic maps, land use - land cover maps, and DTM data sets you have requested for the NALC project. We look forward to collaborating with EPA on the NALC project and on other research projects in the coming years.

Sincerely,
DIRECTOR GENERAL

LIC. NESTOR DUCH GARY

AZM/RSM

Dear Investigator,

The data you have requested of Mexico from the North American Landscape Characterization (NALC) project contains digital elevation data which was provided by Mexico's National Infitute for Statistics, Geography, and Informatics (INEGI). These data sets have been provided by INEGI for use in scientific investigations and projects conducted by government agencies, universities, and non-profit organizations. These data, provided at the marginal costs of distribution, are not to be used for commercial applications. These data sets can be purchased from INEGI by any group wishing to use them in a commercial project.

In order to preserve the commercial markets INEGI has developed for these data sets, we request that you complete the following application and agreement. Your cooperation in abiding by the terms outlined in the agreement will ensure the continued availability of these data sets for scientific research.

The Landsat MSS data sets that you have requested of Mexico are not restricted in their use or distribution.

Please send the completed application and agreement forms to the following address:

Customer Services
USGS EROS Data Center
Mundt Federal Building
Sioux Falls, South Dakota 57198
U.S.A.

Tel. 605-594-6961

No facsimiles of the forms will be accepted.

To obtain the Mexican DTM data for use in a commercial project, please contact INEGI at the following address:

Servicio a Usarios
INEGI, Direccion de Integracion y Analisis
Subdireccion de Comercializacion
Heroe de Nacozari 2301 Puerta 11
Col. del Parque C.P. 20290
Aguascalientes, AGS
MEXICO

Tel. 52-49-181948
FAX 52-49-180739

APPLICATION FOR USE OF THE DIGITAL TERRAIN DATA OF MEXICO

Applicant Name (Last, First, M.I):

Title:

Organization:

Division:

Mailing Address:

Telephone:
Fax:
Electronic Mail:

Title of Research:

Purpose of Usage:

AGREEMENT FOR USE OF THE DIGITAL TERRAIN DATA OF MEXICO

The digital terrain data you have requested of Mexico has been provided by the Mexico's National Institute for Statistics, Geography, and Informatics (INEGI) for use in non-commercial scientific research.

The researcher agrees to the following conditions for use of the Mexican digital terrain data:

1) The data will not be used for commercial purposes.

2) The source of the data (INEGI) will be acknowledged in any derived data product, reports, or publications.

3) The data will not be distributed to third parties. Investigators affiliated with your project who wish to obtain the digital terrain data must complete their own application and agreement forms.

4) The undersigned agree to take appropriate measures to restrict the transfer of the data to commercial entities.

RESEARCHER	ORGANIZATION
Name	Name of Superintendent
Signature / Date	Signature / Date
Address	Address

United States Department of the Interior

GEOLOGICAL SURVEY
EROS Data Center
Sioux Falls, South Dakota 57198

IN REPLY REFER TO: OC 6-4

June 8, 1993

Mr. Nestor Duch Gary
Director d Geographia
Instituto Nacional de Estadistica, Geografia e Informatica
Heroe de Nacozari No. 2301
Puerto 7 Anexo
C.P. 20290 CD, Industrial
Aguascalientes, Mexico

Dear Mr. Duch:

We are pleased to learn of your participation in the North American Landscape Characterization (NALC) Program and your contribution of several data sets, including digital terrain models (DTM's) for all of Mexico. We understand that Mexico's National Institute for Statistics, Geography, and Informatics (INEGI) is providing DTM's for use in the scientific research to be conducted with the NALC data sets. Per your request, the Environmental Protection Agency and the U.S. Geological Survey (USGS) will restrict the access of these data sets to government entities, universities, and non-profit organizations. This will be administered by the USGS EROS Data Center as follows:

-- A user requesting Mexican DTM data will be sent three items (enclosed):

  - a letter explaining data use restrictions,
  - an application for use of the data, and
  - an agreement restricting use and distribution of the data.

-- Upon receipt of both completed forms and proper payment, the Data Center will fill the order.

-- The Data Center will provide copies of completed application and agreement forms to INEGI on a quarterly basis.

We hope that this procedure meets with your approval. We look forward to collaborating with INEGI on the NALC project and on other research projects in the coming years.

Sincerely,

Donald T. Lauer
Chief, EROS Data Center

Enclosures

cc: R. Lunetta, EPA

Dear Investigator,

The data you have requested of Mexico from the North American Landscape Characterization (NALC) project contains digital elevation data which was provided by Mexico's National Institute for Statistics, Geography, and Informatics (INEGI). These data sets have been provided by INEGI for use in scientific investigations and projects conducted by government agencies, universities, and non-profit organizations. These data, provided at the marginal costs of distribution, are not to be used for commercial applications. These data sets can be purchased from INEGI by any group wishing to use them in a commercial project.

In order to preserve the commercial markets INEGI has developed for these data sets, we request that you complete the following application and agreement. Your cooperation in abiding by the terms outlined in the agreement will ensure the continued availability of these data sets for scientific research.

The Landsat MSS data sets that you have requested of Mexico are not restricted in their use or distribution.

Please send the completed application and agreement forms to the following address:

Customer Services
USGS EROS Data Center
Mundt Federal Building
Sioux Falls, South Dakota 57198
USA

Tel. 605-594-6151

No facsimiles of the forms will be accepted.

==

To obtain the Mexican DTM data for use in a commercial project, please contact INEGI at the following address:

Servicio a Usarios
INEGI, Direccion de Integracion y Analisis
Subdireccion de Comercializacion
Heroe de Nacozari 2301 Puerta 11
Col. del Parque C.P. 20290
Aguascalientes, AGS
MEXICO

Tel. 52-49-181948
Fax 52-49-180739

APPLICATION FOR USE OF THE DIGITAL TERRAIN DATA OF MEXICO

Applicant Name (Last, First, M.I.):

Title:

Organization:

Division:

Mailing Address:

Telephone:
Fax:
Electronic Mail:

Title of Research:

Purpose of Usage:

Latitude and Longitude Coverage Limits of Data Requested:

AGREEMENT FOR USE OF THE DIGITAL TERRAIN DATA OF MEXICO

The digital terrain data you have requested of Mexico has been provided by Mexico's National Institute for Statistics, Geography and Informatics (INEGI) for use in non-commercial scientific research.

The researcher agrees to the following conditions for use of the Mexican digital terrain data:

1) The data will not be used for commercial purposes.

2) The sources of the data (INEGI) will be acknowledged in any derived data product, reports, or publications.

3) The data will not be distributed to third parties. Investigators affiliated with your project who wish to obtain the digital terrain data must complete their own application and agreement forms.

4) The undersigned agree to take appropriate measures to restrict the transfer of the data to commercial entities.

RESEARCHER	ORGANIZATION
Name	Name of Superintendent
Signature/Date	Signature/Date
Address	Address

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL MONITORING SYSTEMS LABORATORY-LAS VEGAS
P.O. BOX 93478
LAS VEGAS, NEVADA 89193-3478
(702/798-2100 - FTS 545-2100)

JUN 16 1993

Mr. Nestor Duch Gary
Director General de Geografia
Instituto Nacional Estadistica, Geografia e Informatica
Heroe de Nacozari N. 2301
Puerto 7 Anexo
C.P. 20290 CD, Industrial
Aguascalientes, AGS. Mexico

Dear Mr. Duch:

Thank you for your letter of April 5, 1993 regarding the data exchange agreement between the Instituto Nacional Estadistica, Geografia e Informatica (INEGI) and the Environmental Monitoring Systems Laboratory - Las Vegas (EMSL-LV). The data exchange is being conducted in support of the North American Landscape Characterization (NALC) project, which is a component of the U.S. Global Change Research Program.

In accordance with our data exchange agreement, enclosed please find 19 NALC triplicate data sets for Mexico. We will continue to ship triplicate data sets, in increments of 12 or greater, until all 102 path/rows for Mexico are provided to INEGI.

Also in accordance with your request, the Mexico Digital Terrain Data provided by INEGI will be restricted to noncommercial users of NALC triplicate data sets. The U.S. Geological Survey (USGS), EROS Data Center (EDC) has provided you with correspondence and a copy of the forms "Application or Agreement for the use of the Digital Terrain Data of Mexico", to comply with your distribution restrictions.

To meet the current NALC triplicate data set assembly schedule we would appreciate receipt of Digital Terrain Data for the following coordinates by July 12, 1993.

N 27°, W 99° to N 23°, W 96°
N 33°, W 117° to N 16°, W 99°

We request that the digital terrain data for the remaining locations in Mexico be provided by August 13, 1993.

I have also enclosed a letter request from Ms. Susan K. Jenson of the EDC. Ms. Jenson would like permission from INEGI to produce a 15 arc-second generalized elevation data set for Mexico. This data set would complement similar efforts completed for the United States and Canada. If you would like additional details please contact Ms. Jenson directly at (605)594-6011.

My current travel plans provide an opportunity for me to visit Aguascalientes on September 30, 1993. If this is a good time for you, I would appreciate the opportunity to again visit INEGI. During the visit I could brief you and your staff on the status of the NALC project. Also, I am interested in the progress of your facility upgrades and potential utilization of NALC data sets.

I would like to invite you or member(s) of your staff to attend the next "NALC Technical Work Group" at EMSL - Las Vegas, Nevada on December 8-9, 1993. We could also use the opportunity to tour our facility and brief you on the environmental monitoring research activities at EMSL-LV.

Thank you for your interest and collaboration on the NALC project. I look forward to seeing you on September 30, 1993, in Aguascalientes.

Enclosures

Sincerely,

Ross S. Lunetta

Ross S. Lunetta
NALC Technical Director

CC:
Lauer, USGS/EDC
Sturdevant, USGS/EDC
Jenson, USGS/EDC

Appendix III:

Path/Row Data Acquisition List, Triplicate Assembly Priorities

NALC MSS DATA ACQUISITIONS BY PATH/ROW

(* =PATH/ROWS PURCHASED FROM EOSAT USING EDC BROKERAGE AGREEMENT)

Caribbean 48 scenes.

1/49-50-51-52	
2/48	*48
4/47-48	*47
5/47-48	*47
6/47	
7/46-47	
8/46-47-48	*47,48
9/45-46-47	*45,46,47
10/44-45-46-47	*44,45,46,47
11/43-44-45-46-47-48	*44,45,46,47
12/43 -45-46-47-48	*43,45,46,48
13/42-43-44-45-46	
14/41-42 -44-45	
15/44-45	*45
16/44-45	*45
17/44-45	

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Central America 32 scenes.

10/54-55	
11/54-55	
12/53-54-55	*55
13/54-55	
14/53-54	*53
15/50-51-52-53	
16/49-50-51-52-53	*52,53
17/49-50-51-52	*51,52
18/49-50-51	
19/48-49-50-51	*49,50,51
20/50	*50

==

Chesapeake Bay Watershed 18 scenes.

14/30-31-32-33-34	*30,31,32,33,34
15/30-31-32-33-34	*30,31,32,33,34
16/30-31-32-33-34	*30,31,32,33,34
17/31-32 -34	*31,32,34

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Mexico 119 scenes.

18/45-46	
19/45-46-47	*46
20/45-46-47-48-49	*45,46,47
21/46-47-48-49-50	*46,47,48,50
22/47-48-49	*47,49
23/47-48-49	*48,49
24/46-47-48-49	*48,49
25/45-46-47-48-49	*46,47,48
26/42-43-44-45-46-47-48	
27/42-43-44-45-46-47-48	*45,46,47
28/40-41-42-43-44-45-46-47	*46,47
29/39-40-41-42-43-44-45-46-47	
30/40-41-42-43-44-45-46-47	*40,41,42,43,44,45,46
31/39-40-41-42-43-44	*40,41,42,43
32/38-39-40-41-42-43	*39,40,41,42,43
33/38-39-40-41-42-43-44	*39,40,41,42
34/38-39-40-41-42-43-44	
35/38-39-40-41-42-43	*39
36/38-39-40-41-42	*39,40,41,42
37/38-39-40-41	*40,41
38/37-38-39-40	*38
39/37-38-39	*38
40/37-38	

==

Brazilian MSS Acquisitions 83 scenes.

214/64-65-66-67
215/64-65-66-67-68-69 -71-72-73-74
216/63-64 -69-70-71-72-73-74-75-76
217/63 -70-71-72-73-74-75-76
218/62-63 -70-71-72-73-74-75-76
219/74-75-76-77
220/74-75-76-77-78-79-80-81
221/71 -74-75-76-77-78-79-80-81-82-83
222/74-75-76-77-78-79-80-81-82-83
223/75-76-77-78-79-80
224/75-76-77

(* =PATH/ROWS PURCHASED FROM EOSAT USING EDC BROKERAGE AGREEMENT)

===

Hawaii 8 scenes.

62/46-47
63/46-47
64/45-46
65/45
66/45

===

Alaska 180 scenes.

```
54/21-22
55/21-22
56/20-21
57/19-20-21
58/19-20
59/18-19-20
60/19
61/18
62/17-18
63/17-18
64/16-17-18
65/15-16-17-18
66/14-15-16-17-18
67/13-14-15-16-17-18
68/12-13-14-15-16-17-18
69/11-12-13-14-15-16-17-18-19-20
70/11-12-13-14-15-16-17-18-19-20              *19
71/11-12-13-14-15-16-17-18-19-20
72/11-12-13-14-15-16-17-18-19-20-21           *16
73/11-12-13-14-15-16-17-18-19-20-21
74/10-11-12-13-14-15-16-17-18-19-  -21-22
75/10-11-12-13-14-15-16-17-18-19-  -22
76/10-11-12-13-14-15-16-17-18-19-  -22
77/10-11-12-13-14-15-16-17-18-     -23
78/10-11-12-13-14-15-16-17-18-     -23
79/10-11-12-13-14-15-16-17-18-                *12,13,14,15,16,17
80/10-11-12-13-14-15
81/10-11-12-13-14-15
82/10-11-12-13-14
83/12-13-14
```

(* =PATH/ROWS PURCHASED FROM EOSAT USING EDC BROKERAGE AGREEMENT)

Western US   133 scenes.

33/33-34-35-36-37	*34
34/31-32-33-34-35-36-37	*31,35,36,37,38
35/31-32-33-34-35-36-37	*31,32,33,34,35,36,37,38
36/29-30-31-32-33-34-35-36-37	
37/29-30-31-32-33-34-35-36-37	*37
38/27-28-29-30-31-32-33-34-35-36	*30,33,34,35
39/27-28-29-30-31-32-33-34-35-36	*35,36,37
40/27-28-29-30-31-32-33-34-35-36	
41/26-27-28-29-30-31-32-33-34-35-36-37	
42/26-27-28-29-30-31-32-33-34-35-36	*27,34,36
43/26-27-28-29-30-31-32-33-34-35-36	
44/26-27-28-29-30-31-32-33-34-35	
45/26-27-28-29-30-31-32-33	*28,29,30,31,32,33
46/26-27-28-29-30-31-32	
47/26-27-28-29-30	
48/26-27	

Eastern and Southern US   141 scenes.

06/38
10/29
11/27-28-29- -31
12/27-28-29-30-31
13/28-29-30-31-32
14/29- 35-36
15/29- 35-36-37 -41-42-43
16/35-36-37-38-39-40-41-42
17/30- 33- 35-36-37-38-39-40-41
18/31-32-33-34-35-36-37-38-39
19/31-32-33-34-35-36-37-38-39
20/29-30-31-32-33-34-35-36-37-38-39
21/28-29-30-31-32-33-34-35-36-37-38-39-40
22/27-28-29-30-31-32-33-34-35-36-37-38-39-40
23/27-28-29-30-31-32-33-34-35-36-37-38-39-40
24/27-28-29-30-31-32-33-34-35-36-37-38-39
25/26-27-28-29-30-31-32-33-34-35-36-37-38-39-40

(* =PATH/ROWS PURCHASED FROM EOSAT USING EDC BROKERAGE AGREEMENT)

==

Midwest and Great Plains   122 scenes.

26/27-28-29-30-31-32-33-34-35-36-37-38-39-40-41
27/27-28-29-30-31-32-33-34-35-36-37-38-39-40-41
28/26-27-28-29-30-31-32-33-34-35-36-37-38-39
29/26-27-28-29-30-31-32-33-34-35-36-37-38
30/26-27-28-29-30-31-32-33-34-35-36-37-38-39
31/26-27-28-29-30-31-32-33-34-35-36-37-38
32/26-27-28-29-30-31-32-33-34-35-36-37
33/26-27-28-29-30-31-32
34/26-27-28-29-30
35/26-27-28-29-30
36/26-27-28
37/26-27-28
38/26
39/26
40/26

TOTAL NON-BRAZILIAN NALC SCENES = 801

(* =PATH/ROWS PURCHASED FROM EOSAT USING EDC BROKERAGE AGREEMENT)

EPA 1992-1993 MSS DATA TRIPLICATE PRIORITIES BY PATH/ROW

Priorities are indicated by numbers following the "#" symbol.

==
1993 efforts
==

#1 Southeastern Mexico 39 scenes.

18/45-46
19/45-46-47
20/45-46-47-48-49
21/46-47-48-49-50
22/47-48-49
23/47-48-49
24/46-47-48-49
25/45-46-47-48-49
26/44-45-46-47-48
27/45-46-47-48

#1 Chesapeake Bay Watershed 21 scenes.

14/30-31-32-33-34
15/30-31-32-33-34
16/30-31-32-33-34
17/31-32-33-34
18/33-34

#1 Oregon Transect 2 scenes.

45/29
46/29

Priority total = 62 scenes.

#2 Central America 32 scenes.

10/54-55
11/54-55
12/53-54-55
13/54-55
14/53-54
15/50-51-52-53
16/49-50-51-52-53
17/49-50-51-52
18/49-50-51
19/48-49-50-51
20/50

#2 Caribbean 48 scenes.

1/49-50-51-52
2/48
4/47-48
5/47-48
6/47
7/46-47
8/46-47-48
9/45-46-47
10/44-45-46-47
11/43-44-45-46-47-48
12/43 -45-46-47-48
13/42-43-44-45-46
14/41-42 -44-45
15/44-45
16/44-45
17/44-45

#2 Hawaii 8 scenes.

62/46-47
63/46-47
64/45-46
65/45
66/45

Priority total = 88 scenes.

#3 US Great Lakes Watershed 35 scenes.

15/29
17/30
18/31-32
19/31-32
20/29-30-31-32
21/28-29-30-31
22/27-28-29-30-31
23/27-28-29-30-31
24/27-28-29-30
25/26-27-28
26/27-28
27/27-28

(note that some triplicates made for the Chesapeake Bay Watershed also include portions of the US Great Lakes Watershed).

#3 US/Mexico Border 20 scenes.

26/42-43
27/42
28/40-41
29/40
30/40
31/40
32/39
33/38-39
34/38
35/38
36/38
37/38
38/38
39/37-38
40/37-38

#3 Southeastern US 19 scenes.

16/36-37
17/35-36-37
18/35-36-37 -39
19/34-35-36-37
20/34-35-36-37
21/35-36

Priority total = 74 scenes.

#4 Mexico Forested Regions 37 scenes.

28/46-47
29/47
30/45-46-47
31/44
32/40-41-42-43
33/40-41-42-43-44
34/39-40-41-42-43-44
35/39-40-41-42-43
36/39-40-41-42
37/39-40-41
38/39-40
39/39

#4 Western USA 130 scenes.

31/39
33/33-34-35-36-37
34/31-32-33-34-35-36-37
35/31-32-33-34-35-36-37
36/29-30-31-32-33-34-35-36-37
37/29-30-31-32-33-34-35-36-37
38/29-30-31-32-33-34-35-36-37
39/29-30-31-32-33-34-35-36
40/26-27-28-29-30-31-32-33-34-35-36
41/26-27-28-29-30-31-32-33-34-35-36-37
42/26-27-28-29-30-31-32-33-34-35-36
43/26-27-28-29-30-31-32-33-34-35-36
44/26-27-28-29-30-31-32-33-34-35
45/26-27-28 -30-31-32-33
46/26-27-28 -30-31-32
47/26-27-28-29-30
48/26-27

Priority total = 167 scenes.

Year total = 391 scenes.

==

1994 efforts

==

#5 Alaska 180 scenes.

54/21-22
55/21-22
56/20-21
57/19-20-21
58/19-20
59/18-19-20
60/19
61/18
62/17-18
63/17-18
64/16-17-18
65/15-16-17-18
66/14-15-16-17-18
67/13-14-15-16-17-18
68/12-13-14-15-16-17-18
69/11-12-13-14-15-16-17-18-19-20
70/11-12-13-14-15-16-17-18-19-20
71/11-12-13-14-15-16-17-18-19-20
72/11-12-13-14-15-16-17-18-19-20-21
73/11-12-13-14-15-16-17-18-19-20-21
74/10-11-12-13-14-15-16-17-18-19- -21-22
75/10-11-12-13-14-15-16-17-18-19- -22
76/10-11-12-13-14-15-16-17-18-19- -22
77/10-11-12-13-14-15-16-17-18- -23
78/10-11-12-13-14-15-16-17-18- -23
79/10-11-12-13-14-15-16-17-18
80/10-11-12-13-14-15
81/10-11-12-13-14-15
82/10-11-12-13-14
83/12-13-14

#6 Eastern and Southeastern US 88 scenes.

06/38
10/29
11/27-28-29 -31
12/27-28-29-30-31
13/28-29-30-31-32
14/29- 35-36
15/35-36-37 -41-42-43
16/35- 38-39-40-41-42
17/38-39-40-41
18/38
19/33 -38-39
20/33 -38-39
21/32-33-34 -37-38-39-40
22/32-33-34-35-36-37-38-39-40
23/32-33-34-35-36-37-38-39-40
24/31-32-33-34-35-36-37-38-39
25/29-30-31-32-33-34-35-36-37-38-39-40

#7 Non-Forested Mexico 19 scenes.

27/43-44
28/42-43-44-45
29/41-42-43-44-45-46
30/41-42-43-44
31/41-42-43

#8 Midwest and Great Plains 123 scenes.

26/29-30-31-32-33-34-35-36-37-38-39-40-41
27/29-30-31-32-33-34-35-36-37-38-39-40-41
28/26-27-28-29-30-31-32-33-34-35-36-37-38-39
29/26-27-28-29-30-31-32-33-34-35-36-37-38-39
30/26-27-28-29-30-31-32-33-34-35-36-37-38-39
31/26-27-28-29-30-31-32-33-34-35-36-37-38
32/26-27-28-29-30-31-32-33-34-35-36-37-38
33/26-27-28-29-30-31-32
34/26-27-28-29-30
35/26-27-28-29-30
36/26-27-28
37/26-27-28
38/26-27-28
39/26-27-28

Year total = 410 scenes.

Grand total = 801 scenes.

Appendix IV:

Triplicate Image Selection for all Path/Rows

Caribbean

Central America

Chesapeake Bay Watershed

Mexico

Hawaii

Alaska

Western US

Eastern and Southern US

Midwest and Great Plains US

The following lists provide suggested triplicate images for production. The entries are listed by region, and identified by the path / row scene identification numbers for Landsat World Reference System 2 (WRS-2). Also listed are the selected scene dates, Landsat scene identification numbers, and for 70's epoch scenes the WRS-1 identifiers that are correlated to the WRS-2 scenes are provided.

Some comments are included. They include: suggestions as to making Reduced Cloud Composites, "Composite" or "Composite with" or "Composite 3" when a third image may be necessary; suggestions for EDC to examine the images again, "EROS Check"; suggestions that a second WRS-1 scene may be unnecessary, "Second WRS-1 scene not required ?"; indications that the microfiche image is unsuitable to judge image quality, "fiche missing" or "bad fiche" or "black fiche" or "faded fiche"; or suggestions to check for available scenes using the EDC metadata system, "GLIS all 90's" or "GLIS for ID".

NALC MSS Triplicates - Caribbean

Path 01 Row 49

	92/04/01	LM84354713304x0	
	86/04/25	LM85078513512x0	Composite with
	86/03/24	LM85075313521x0	
01/49	72/10/14	LM8108314000500	

Second WRS-1 not required?

Path 01 Row 50

	92/09/08	LM84370713361x0	Composite with
	92/07/22	LM84365913345x0	
	86/01/19	LM85068913535x0	Composite with
	86/01/03	LM85067313541x0	
251/50	73/03/24	LM8124413553500	

Second WRS-1 not required?

Path 01 Row 51

	92/04/17	LM84356313320x0	
	86/01/19	LM85068913542x0	Composite with
	86/01/03	LM85067313544x0	
251/51	73/03/24	LM8124413560500	

Second WRS-1 not required?

Path 01 Row 52

	92/04/17	LM84356313322x0	
	86/01/19	LM85068913544x0	Composite with
	86/01/03	LM85067313550x0	
251/52	75/12/18	LM8233013415500	

Second WRS-1 not required?

Path 02 Row 48

	92/03/07	LM84352213361x0	
	86/03/15	LM85074413580x0	Composite with
	86/01/10	LM85068013593x0	
01/48	73/02/17	LM8120914001500	

Second WRS-1 not required?

Path 04 Row 47

	92/08/12	LM84368013525x0	
	85/01/21	LM85032614142x0	
04/47	73/03/10	LM8123014171500	Composite with
	73/01/15	LM8117614162500	

Second WRS-1 not required?

Path 04 Row 48

	92/08/12	LM84368013531x0	Composite with
	92/06/25	LM84363213514x0	
	83/02/09	LM84020814134x0	
04/48	73/03/10	LM8123014174500	

Second WRS-1 not required?

Path 05 Row 47

	92/05/31	LM84360713564x0	
	83/06/24	LM84034314200x0	
04/47	73/03/10	LM8123014171500	Composite with
	73/01/15	LM8117614162500	
05/47	78/03/30	LM82116313442x0	

Path 05 Row 48

	92/08/19	LM84368713593x0
	85/01/12	LM85031714205x0
04/48	73/03/10	LM8123014174500
05/48	78/03/30	LM82116313445x0

Path 06 Row 47

	92/04/20	LM84356614012x0	Composite 3
	92/04/04	LM84355014005x0	
	92/03/03	LM84351814003x0	
	86/01/06	LM85067614235x0	
06/47	79/01/31	LM82152414062x0	

Second WRS-1 not required?

Path 07 Row 46

No 1990's

	86/01/13	LM85074714281x0
07/46	79/02/01	LM82152414052x0

Second WRS-1 not required?

Path 07 Row 47

	92/05/13	LM84358914082x0
	85/05/02	LM85042714324x0
07/47	73/12/08	LM8150314311500

Second WRS-1 not required?

Path 08 Row 46

	92/05/04	LM84358014135x0	
	86/07/31	LM85088214303x0	
08/46	72/08/28	LM8103614384500	
09/46	75/02/06	LM8201514332500	

Path 08 Row 47

	92/05/20	LM84359614145x0	Composite with
	92/05/04	LM84358014141x0	
	86/01/20	LM85069014360x0	
08/47	73/12/09	LM8150414365500	
09/47	75/02/06	LM8201514334500	

Path 08 Row 48

	92/05/20	LM84359614151x0	
	86/03/09	LM85073814352x0	
08/48	73/12/09	LM8150414372500	

Second WRS-1 not required.

Path 09 Row 45

	92/07/30	LM84366714223x0	
	86/01/11	LM85068114413x0	
09/45	78/09/03	LM83018214333x0	

Second WRS-1 not required?

Path 09 Row 46

	92/06/12	LM84363514215x0
	86/01/11	LM85068114420x0
09/46	75/02/06	LM8201514332500
10/46	74/01/16	LM8154214470500

Path 09 Row 47

	92/08/15	LM84368314235x0
	86/09/08	LM85092114354x0
09/47	74/02/06	LM8201514334500
10/47	74/01/16	LM8154214472500

Path 10 Row 44

	92/09/07	LM84370614293x0
	86/08/14	LM85089614413x0
11/44	76/03/28	LM8243114393500

Second WRS-1 not required?

Path 10 Row 45

	92/05/02	LM84357814254x0
	85/06/08	LM85046414502x0
10/45	78/11/15	LM83025514394x0

Second WRS-1 not required?

Path 10 Row 46

	92/06/03	LM84361014272x0	Composite with
	92/05/02	LM84357814260x0	
	85/06/08	LM85046414505x0	
11/46	76/03/28	LM8243114402500	

Second WRS-1 not required.

Path 10 Row 47

	92/03/31	LM84354614253x0
	85/06/08	LM85056414511x0
10/47	74/01/16	LM8154214472500

Second WRS-1 not required?

Path 11 Row 43

DOUBLET !!!

	86/03/14	LM85074314514x0
12/43	73/04/05	LM8125615013500

Second WRS-1 not required?

Path 11 Row 44

	92/04/23	LM84356914311x0
	85/04/28	LM85042314561x0
11/44	76/03/28	LM8243114393500

Second WRS-1 not required?

Path 11 Row 45

	92/08/29	LM84369714354x0	
	85/02/07	LM85034314565x0	
12/45	80/06/24	LM82198014482x0	

Path 11 Row 46

	92/04/23	LM84356914320x0	
	86/02/10	LM85071114534x0	
11/46	76/03/28	LM8243114402500	
12/46	73/02/10	LM8120215023500	

Path 11 Row 47

	92/08/13	LM84368114360x0	
	87/05/04	LM85115914504x0	
12/47	73/02/10	LM8120215023500	

Second WRS-1 not required?

Path 11 Row 48

	92/02/19 92/03/22	LM84350514324x0 LM84353714315x0	Composite with
	84/08/15	LM850167145572x0	
12/48	79/02/15 78/11/17	LM83034714521x0 LM83025714520x0	OR EROS CHECK

Second WRS-1 not required?

Path 12 Row 43

	92/03/29	LM84354414361x0	
	86/01/16	LM85068614591x0	
12/43	73/04/05	LM8125615013500	

Second WRS-1 not required?

Path 12 Row 45

	92/03/29	LM84354414370x0	Composite with
	92/03/13	LM84352814365x0	
	86/02/17	LM85071814591x0	
12/45	80/06/24	LM82198014482x0	
13/45	78/12/24	LM83029414563x0	

Path 12 Row 46

	92/03/29	LM84354414372x0
	86/02/17	LM85071814594x0
12/46	73/02/10	LM8120215023500
13/46	73/01/06	LM8116715075500

Path 12 Row 47

	92/07/19	LM84365614413x0
	86/07/27	LM85087814554x0
12/47	73/02/10	LM8120215025500
13/47	73/01/06	LM8116715081500

Path 12 Row 48

	92/04/30	LM84357614391x0	
	87/02/04	LM85107014541x0	
12/48	79/02/15	LM83034714521x0	OR
	78/10/30	LM83023914522x0	EROS Check

Second WRS-1 not required?

Path 13 Row 42

	92/03/20	LM84353514415x0
	86/04/29	LM85078915024x0
14/41	72/10/09	LM8107815111500
14/42	73/03/20	LM8124015123500

Path 13 Row 43

	92/03/20	LM84353514422x0
	86/04/29	LM85078915030x0
14/43	73/03/20	LM8124015130500

Second WRS-1 not required?

Path 13 Row 44

	92/02/25	LM85291715023x0
	86/04/29	LM85078915033x0
13/44	72/09/02	LM8104115063500

Second WRS-1 not required?

Path 13 Row 45

	92/02/25	LM85291715030x0
	86/02/24	LM85072515052x0
13/45	78/12/24	LM83029414563x0
14/45	75/06/26	LM8506814501500

Path 13 Row 46

	92/02/25	LM85291715032x0
	86/02/24	LM85072515054x0
13/46	78/12/24	LM83029414563x0

Second WRS-1 not required?

Path 14 Row 41

	92/03/19	LM85294015073x0
	85/05/03	LM85042815133x0
15/41	73/04/26	LM8127715174500

Second WRS-1 not required?

Path 14 Row 42

	92/03/19	LM85294015080x0
	86/04/20	LM85078015090x0
14/42	73/03/20	LM8124015123500
15/42	75/02/03	LM8192515015500

Path 14 Row 44

	92/08/02	LM84367014531x0	Composite with
	92/07/01	LM84363814521x0	
	86/09/27	LM85092415051x0	Composite with
	86/09/11	LM85092415051x0	
14/44	75/06/26	LM8506814501500	
15/44	80/09/07	LM82205515061x0	

Path 14 Row 45

	92/08/02	LM84367014533x0	Composite with
	92/07/01	LM84363814523x0	
	87/09/30	LM85130815121x0	
14/45	75/06/26	LM8506814501500	
15/45	76/04/01	LM8243515025500	

Path 15 Row 44

	92/03/10	LM85293115150x0
	86/02/22	LM85072315172x0
15/44	80/09/07	LM82205515061x0
16/44	72/08/18	LM8102615235500

Path 15 Row 45

	92/07/24	LM84366114592x0
	86/08/01	LM85088315132x0
16/44	72/08/18	LM8102615235500

Second WRS-1 not required?

Path 16 Row 44

	92/05/28	LM84360415032x0	
	86/04/18	LM85077815222x0	
16/44	72/08/18	LM8102615235500	
17/44	79/02/02	LM83033415191x0	

Path 16 Row 45

	92/07/15 92/06/13	LM84365215052x0 LM84362015041x0	Composite with
	85/03/30 85/03/14	LM85039415274x0 LM85037815275x0	Composite with
17/45	73/07/09	LM8135115301500	

Second WRS-1 not required.

Path 17 Row 44

	92/09/08	LM84370715124x0	
	86/07/30	LM85088115252x0	
18/44	72/10/31	LM8110015354500	

Second WRS-1 not required?

Path 17 Row 45

	92/03/08	LM85292915274x0	
	86/07/30	LM85088115254x0	
18/45	78/11/05	LM83024515253x0	

Second WRS-1 not required?

NALC MSS Triplicates - Central American

Path 10 Row 54 To be selected

Path 10 Row 55 To be selected

Path 11 Row 54

	92/05/25	LM84360114362x0	
	85/02/07	LM85034315003x0	
11/54	No low cloud data.		
12/54	74/02/23	LM8158015004500	

Path 11 Row 55

	92/04/15	LE85296714542x0	Composite with
	92/02/27	LE85291914543x0	
	85/02/23	LM85035915005x0	Composite with
	85/02/07	LM85034315005x0	
11/55	No low cloud 1970's data.		
12/55	No low cloud 1970's data.		

Path 12 Row 53

	92/04/22	LE85297414594x0	
	86/02/01	LM85068615031x0	Composite with
	86/01/16	LM85068615031x0	
12/53	No low cloud 1970's data.		

Path 12 Row 54

	92/04/22	LE85297415000x0	
	87/01/19	LM85105414560x0	Composite with
	87/01/03	LM85103814553x0	
12/54	74/02/23	LM8158015004500	
13/54	74/02/24	LM8158115063500	

Path 12 Row 55

	92/04/22	LE85297415003x0	
	85/03/18	LM85038215070x0	
12/55	No low cloud 1970's data.		
13/55	73/03/19	LM8123915121500	

Path 13 Row 54

	92/03/28 92/03/12	LE85294915063x0 LE85293315063x0	Composite with
	87/03/15	LM85110915041x0	
13/54	74/02/24	LM8158115063500	
14/54	74/01/20	LM8154615130500	

Path 13 Row 55

	92/03/12	LE85293315070x0
	86/03/28	LM85075715084x0
13/55	73/03/19	LM8123915121500

Second WRS-1 not required?

Path 14 Row 53

	92/05/14 92/03/27	LE84359014541x0 LE84354214523x0	Composite with
	87/02/18 87/02/02	LM85108415091x0 LM85106815083x0	Composite with
15/53	74/05/09	LM8165515160500	

Second WRS-1 not required???

Path 14 Row 54

	92/04/20	LE85297215123x0	
	92/03/03	LE85292415124x0	
	87/02/18	LM85108415093x0	Composite 3
	87/02/02	LM85106815085x0	
	87/01/01	LM85103615075x0	
14/54	79/01/30	LM83033115061x0	
15/54	79/01/22	LM82146114582x0	

Path 15 Row 50

	92/08/09	LE84367715015x0	
	86/02/22	LM85072315194x0	Composite with
	86/02/06	LM85070715200x0	
16/50	78/04/01	LM83002715141x0	

Second WRS-1 not required.

Path 15 Row 51

	92/05/05	LE84358114591x0
	87/10/07	LM85131515205x0
16/51	78/04/01	LM83002715144x0

Second WRS-1 not required.

Path 15 Row 52

	92/05/05	LE84358114593x0	
	85/04/24	LM85041915241x0	Composite with
	85/04/08	LM85040315242x0	
16/52	78/04/01	LM83002715150x0	

Second WRS-1 not required.

Path 15 Row 53

	92/05/13	LE85299515180x0	
	86/02/06	LM85072315205x0	
15/53	74/05/09	LM8165515160500	
16/53	75/03/03	LM8204015163500	

Path 16 Row 49

	92/04/02	LE85295415230x0	
	86/01/28	LM85069815260x0	
16/49	78/04/19	LM83004515140x0	
17/49	78/04/02	LM83002815193x0	

Path 16 Row 50

	92/04/02 92/03/01	LM85295415232x0 LM85292215233x0	Composite with
	86/01/28	LM85069815262x0	
16/50	78/04/01	LM83002715141x0	
17/50	76/03/16	LM8241915165500	

Path 16 Row 51

	92/04/26 92/03/01	LM84357215045x0 LM85292215235x0	Composite with
	86/01/28	LM85069815265x0	
16/51	78/04/01	LM83002715144x0	
17/51	78/04/02	LM83002815202x0	

Path 16 Row 52

	92/03/01	LE85292215242x0	
	86/04/02	LM85076215255x0	
16/52	78/04/01	LM83002715150x0	
17/52	78/04/02	LM83002815205x0	

Path 16 Row 53

	92/03/01	LE85292215244x0	
	86/03/01	LM85073015265x0	
16/53	75/03/03	LM8204015163500	
17/53	78/04/02	LM83002815211x0	

Path 17 Row 49

	92/04/01 92/03/08	LE84354715093x0 LE85292915292x0	Composite with
	86/03/08	LM85073715312x0	
17/49	78/04/02	LM83002815193x0	
18/49	73/12/19	LM8151415345500	

Path 17 Row 50

	92/03/08	LE85292915294x0	
	85/02/01	LM85033715355x0	
17/50	76/03/16	LM8241915165500	
18/50	75/03/23	LM8206015263500	

Path 17 Row 51

	92/04/01	LE84354715102x0	Composite with
	92/03/08	LE85292915300x0	
	85/02/01	LM85033715362x0	
17/51	78/04/02	LM83002815202x0	
18/51	72/12/24	LM8115415385500	

Path 17 Row 52

	92/04/01	LE84354715104x0
	86/02/20	LM85072115325x0
17/52	78/04/02	LM83002815205x0

Second WRS-1 not required?

Path 18 Row 49

	92/03/23	LE84353815153x0
	86/03/15	LM85074415372x0
18/49	73/12/19	LM8151415345500
19/49	78/12/21	LM82142915180x0

Path 18 Row 50

	92/03/23	LE84353815160x0
	86/03/15	LM85074415375x0
18/50	75/03/23	LM8206015263500
19/50	74/03/02	LM8158715391500

Path 18 Row 51

	92/03/23	LE84353815162x0	
	86/03/31	LM85076015375x0	
18/51	72/12/24	LM8115415385500	
19/51	75/03/06	LM8204315323500	

Path 19 Row 48

	92/06/02	LM84360915234x0	Composite with
	92/03/30	LM84354515213x0	
	86/08/29	LM85091115381x0	Composite with
	86/07/28	LM85087915392x0	
20/48	75/03/25	LM8206215371500	

Second WRS-1 not required.

Path 19 Row 49

	92/05/01	LE84357715225x0	Composite with
	92/03/30	LE84354515215x0	
	87/12/14	LM84197715394x0	
20/49	75/03/25	LM8206215373500	

Second WRS-1 not required.

Path 19 Row 50

	92/05/01	LE84357715231x0	
	86/04/07	LM85076715433x0	
20/50	78/12/31	LM83030115385x0	

Second WRS-1 not required.

Path 19 Row 51

	92/05/01	LE84357715234x0
	86/03/22	LM85075115441x0
20/51	73/02/18	LM8121015503500

Second WRS-1 not required?

Path 20 Row 50

	92/03/21	LE84353615282x0	Composite with
	92/04/22	LE84356815291x0	
	86/03/13	LM85074215501x0	
21/50	76/03/02	LM8240515402500	

Second WRS-1 not required?

NALC MSS Triplicates - Chesapeake Bay Watershed

Path 14 Row 30

	91/09/09	LM85274815025x0
	86/08/26	LM85090815001x0
15/30	73/07/07	LM8134915123500

Second WRS-1 not required?

Path 14 Row 31

	91/06/21	LM85266815022x0
	87/06/10	LM85119615035x0
15/31	73/07/07	LM8134915125500
	73/07/24	LM8136615065500

Path 14 Row 32

	91/06/21	LM85266815025x0
	87/06/10	LM85119615041x0
15/32	73/08/30	LM8140315123500

Second WRS-1 not required?

Path 14 Row 33

	91/09/09	LM85274815040x0
	87/06/10	LM85119615044x0
15/33	73/08/30	LM8140315125500
	73/08/29	LM8140215071500

Path 14 Row 34

	91/09/09	LM85274815043x0
	85/06/20	LM85047615104x0
15/34	73/08/12	LM8138515134500

Second WRS-1 not required?

Path 15 Row 30

	90/09/13	LM85238715050x0
	87/06/17	LM85120315095x0
16/30	73/08/30	LM8140315114500
17/30	72/08/19	LM8102715233500

Path 15 Row 31

	90/08/12	LM85235515053x0
	87/06/17	LM85120315101x0
16/31	73/07/08	LM8135015183500

Second WRS-1 not required?

Path 15 Row 32

	90/07/27	LM85233915060x0
	87/06/17	LM85120315104x0
16/32	73/07/03	LM8135015190500

Second WRS-1 not required?

Path 15 Row 33

	90/06/25	LM85230715063x0
	87/06/17	LM85120315110x0
16/33	73/07/08	LM8135015192500

Second WRS-1 not required?

Path 15 Row 34

	90/06/25	LM85230715070x0
	85/08/14	LM85053115163x0
16/34	73/08/31	LM8140415190500

Second WRS-1 not required?

Path 16 Row 30

	91/08/22	LM85273015150x0
	86/07/23	LM85087415135x0
17/30	74/07/22	LM8172915153500

Path 16 Row 31

	91/08/07	LM85274615154x0
	86/09/09	LM85092215123x0
17/31	72/09/06	LM8104515240500

Path 16 Row 32

	91/09/07	LM85274615160x0
	86/09/09	LM85092215125x0
17/32	72/09/06	LM8104515243500

Second WRS-1 not required?

Path 16 Row 33

	91/09/07	LM85274615162x0
	86/09/09	LM85092215132x0
17/33	76/09/12	LM8259915045500

Second WRS-1 not required?

Path 16 Row 34

	90/08/30	LM85234615130x0
	87/06/08	LM85119415172x0
17/34	75/08/22	LM8512514593500

Second WRS-1 not required?

Path 17 Row 31

	92/06/10	LM85265715204x0
	87/06/15	LM85120115223x0
18/31	75/06/04	LM8215015184500

Path 17 Row 32

	91/08/13	LM85272115215x0
	85/08/12	LM85052915280x0
18/32	75/06/21	LM8215015190500

Path 17 Row 34

	92/09/14	LM85275315230x0
	86/07/14	LM85086515215x0
18/34	73/09/02	LM8140615303500

NALC MSS Triplicates - Mexico

Path 18 Row 45 To be selected

Path 18 Row 46 To be selected

Path 19 Row 45

	90/11/04	LM84303315422x0	EROS CHECK
	86/07/28	LM85087915381x0	Composite
	86/07/12	LM85086315384x0	
20/45	76/01/07	LM8235015333500	

Second WRS-1 not required?

Path 19 Row 46

	92/05/01	LE84357715214x0	
	86/12/19	LM85102315351x0	Composite
	86/12/03	LM85100715344x0	
20/46	76/02/12	LM8238615332500	

Second WRS-1 not required?

Path 19 Row 47

	90/11/20	LM84304915424x0
	84/11/11	LM85025515463x0
20/47	75/12/02	LM8231415344500

Second WRS-1 not required?

Path 20 Row 45

	90/04/17	LM84283215531x0	
	86/03/13	LM85074215481x0	
21/45	74/03/04	LM8158915483500	
22/45	75/11/16	LM8229815453500	

Path 20 Row 46

	92/05/08	LE84358415281x0	
	86/03/13	LM85074215483x0	
21/46	76/04/07	LM8244115373500	
22/46	76/02/14	LM8238815445500	OR
	72/08/24	LM8103215585500	EROS CHECK

Path 20 Row 47

	90/04/17	LM84283215540x0	
	86/04/14	LM85077415482x0	Composite
	86/03/13	LM85074215490x0	
21/47	78/01/15	LM82108915121x0	
22/47	74/02/15	LM8103215592500	

Path 20 Row 48

	90/04/17	LM84283215542x0	
	86/04/14	LM85077415484x0	
21/48	74/02/14	LM8157115500500	

Second WRS-1 not required?

Path 20 Row 49

No 90's data?		Doublet not triplet.	
	86/03/13	LM85074215495x0	
21/49	79/02/15	LM83033815441x0	

Path 21 Row 46 To be selected

Path 21 Row 47

	92/08/27	LE85310115512x0	OR
	90/12/20	LM84307915540x0	EROS CHECK
	84/11/25	LM85026915590x0	
22/47	74/02/15	LM8157215552500	
23/47	78/09/17	LM83019615545x0	OR
	80/11/17	LM83098815410x0	EROS CHECK

Path 21 Row 48

	92/08/27	LE85310115515x0
	84/11/25	LM85026915592x0
22/48	74/02/15	LM8157215554500
23/48	75/12/05	LM8231715522500

Path 21 Row 49

	90/12/20	LE84307915545x0	EROS CHECK
	86/01/15	LM85068515571x0	
22/49	74/02/15	LM8157215561500	
23/49	75/12/05	LM8231715524500	

Path 21 Row 50

	90/10/01	LM84299915574x0	
	90/08/06	LM85234915501x0	
	86/01/15	LM85068515574x0	
22/50	74/02/15	LM8157215563500	

Second WRS-1 not required?

Path 22 Row 47

	92/04/20	LE84356615401x0	
	86/04/12	LM85077216004x0	
23/47	78/09/17	LM83019615545x0	
24/47	72/12/30	LM8116016112500	

Path 22 Row 48

	90/11/25	LM84305416013x0	Composite
	90/11/09	LM84303816015x0	
	84/01/09	LM84054216040x0	
23/48	80/11/17	LM83098815412x0	
24/48	76/05/16	LM8248015542500	

Path 22 Row 49

	92/04/04	LE84355015403x0	Composite
	92/03/03	LE84351815401x0	
	86/03/11	LM85074016021x0	
23/49	75/12/05	LM8231715524500	
24/49	73/01/17	LM8117816115500	

Path 23 Row 47

	90/12/18	LE84307716063x0	EROS CHECK
	86/03/18	LM85074716072x0	
24/47	72/12/30	LM8116016112500	
25/47	76/04/11	LM8244516004500	Composite
	76/03/24	LM8242716012500	

Path 23 Row 48

	90/12/18	LE84307716065x0	EROS CHECK
	86/05/05	LM85079516064x0	Composite
	86/04/03	LM85076316073x0	
24/48	76/05/16	LM8248015542500	
25/48	79/02/28	LM83036016063x0	

Path 23 Row 49

	92/04/11	LE84355715465x0	
	86/04/19	LM85077916073x0	
24/49	73/01/17	LM8117816115500	Composite
	72/12/30	LM8116016121500	
25/49	73/11/20	LM8148516153500	

Path 24 Row 46 To be selected

Path 24 Row 47

	90/08/27	LM85237016073x0	
	87/08/19	LM85126616134x0	Composite
	87/08/03	LM85125016132x0	
25/47	73/02/05	LM8119716172500	
26/47	73/05/25	LM8130616231500	

Path 24 Row 48

	92/04/18	LE84356415530x0	Composite
	92/04/02	LE84354815522x0	
	86/04/10	LM85077016133x0	Composite
	86/03/25	LM85075416135x0	
25/48	79/03/09	LM82150715551x0	Composite
	79/02/28	LM83036016063x0	
26/48	73/01/19	LM8118016231500	OR
	73/05/25	LM8130616233500	EROS CHECK

Path 24 Row 49

	92/04/18	LE84356415532x0
	86/03/25	LM85075416141x0
25/49	73/11/20	LM8148516153500
26/49	74/02/01	LM8155816192500

Path 25 Row 45

	89/10/10	LM84265916261x0
	86/01/27	LM85069716200x0
27/45	72/11/09	LM8110916275500

Path 25 Row 46

	89/11/11	LM84267516263x0	
	84/12/23	LM85029716233x0	
26/46	73/05/25	LM8130616224500	Composite
	73/03/14	LM8123416230500	
27/46	73/04/20	LM8127116284500	

Path 25 Row 47

	92/05/27	LE84360316001x0	
	86/04/17	LM85077716191x0	Composite
	86/03/16	LM85074516195x0	
26/47	73/05/25	LM8130616231500	
27/47	73/02/27	LM8119916285500	

Path 25 Row 48

	90/12/16	LE84307516192x0	EROS CHECK
	86/01/27	LM85069716212x0	
26/48	73/01/19	LM8118016231500	OR
	73/05/25	LM8130616233500	EROS CHECK
27/48	79/02/03	LM82147316050x0	

Path 25 Row 49

	90/08/02	LM85234516143x0	
	84/12/23	LM85029716244x0	
26/49	74/02/01	LM8155816192500	
27/49	74/02/20	LM8157716245500	

Path 26 Row 42

	92/07/29	LE85312016200x0	Composite
	92/06/27	LE85304016211x0	
	87/08/17	LM85126416240x0	EROS CHECK
28/42	73/09/12	LM8141616310500	

Second WRS-1 not required.

Path 26 Row 43

	90/10/20	LM84301816252x0
	85/10/30	LM85060816271x0
28/43	74/09/07	LM8177616221500

Second WRS-1 not required.

Path 26 Row 44

	90/10/20	LM84301816254x0
	85/10/30	LM85060816273x0
27/44	72/11/09	LM8110916273500
28/44	73/05/27	LM8130816332500

Path 26 Row 45

	90/10/20	LM84301816260x0
	85/10/30	LM85060816275x0
27/45	72/11/09	LM8110916275500
28/45	73/05/27	LM8130816334500

Path 26 Row 46

	90/11/21	LM84305016253x0
	85/10/30	LM85060816282x0
27/46	73/04/20	LM8127116284500
28/46	73/11/23	LM8148816312500

Path 26 Row 47

	89/03/07	LM84242616325x0
	85/01/31	LM85033616302x0
27/47	73/02/07	LM8119916285500
28/47	73/11/23	LM8148816315500

Path 26 Row 48

	92/05/18	LE84359416063x0
	86/04/24	LM85078416253x0
27/48	79/02/03	LM82147316050x0
28/48	73/03/16	LM8123616352500

Use as much of 73/03/16 as possible.

Path 27 Row 42

	91/07/18	LE85269516273x0
	86/07/04	LM85085516271x0
28/42	73/09/12	LM8141616310500
29/42	74/03/30	LM8161516324500

Path 27 Row 43

	92/04/07	LE84355316090x0	
	86/05/01	LM85079116293x0	Composite
	86/03/14	LM85074316304x0	
28/43	73/05/27	LM8130816325500	
29/43	73/03/17	LM8123716390500	

Path 27 Row 44

	92/05/09	LE84358516104x0	Composite
	92/04/07	LE84355316093x0	
	86/03/14	LM85074316310x0	
28/44	73/05/27	LM8130816332500	
29/44	73/05/10	LM8129116391500	

Path 27 Row 45

	92/05/09	LE84358516110x0	
	83/05/17	LM84030516350x0	
28/45	73/05/27	LM8130816334500	
29/45	76/03/28	LM8243116231500	

Path 27 Row 46

	92/05/25	LE84360116120x0	Composite
	92/05/09	LE84358516113x0	
	86/03/14	LM85074316315x0	
28/46	73/04/21	LM8127216343500	
29/46	76/03/28	LM8243116234500	

Path 27 Row 47

	92/09/06	LE85311116282x0
	86/03/14	LM85074316321x0
28/47	73/11/23	LM81488163155OO
29/47	76/03/28	LM8243116240500

Path 27 Row 48

DOUBLET

	86/03/14	LM85074316324x0
28/48	73/03/16	LM8123616352500
29/48	76/03/28	LM8243116243500

Path 28 Row 40

	92/06/25	LE85303816324x0
	86/07/27	LM85087816315x0
30/40	73/05/29	LM8131016431500

Second WRS-1 not required?

Path 28 Row 41

	92/06/25	LE85303816331x0
	86/07/27	LM85087816321x0
29/41	74/09/08	LM8177716271500
30/41	73/05/29	LM8131016433500

Path 28 Row 42

	90/03/16	LM85220616305x0
	83/04/22	LM84028016401x0
29/42	74/03/20	LM8161516324500
30/42	76/04/16	LM8245016271500

Path 28 Row 43

	90/03/16	LM85220616311x0
	83/04/22	LM84028016403x0
29/43	73/03/17	LM8123716390500
30/43	74/06/29	LM8170616361500

Path 28 Row 44

	92/04/30	LE84357616162x0
	83/04/22	LM84028016410x0
29/44	73/05/10	LM8129116391500
30/44	73/03/18	LM8123816451500

Path 28 Row 45

	90/03/16	LM85220616320x0
	86/04/06	LM85076616371x0
29/45	76/03/28	LM8243116231500
30/45	76/03/20	LM8533616053500

Path 28 Row 46

	92/04/30	LE84357616171x0	
	86/04/06	LM85076616373x0	
29/46	76/03/28	LM8243116234500	
30/46	73/05/11	LM8129216455500	OR
	76/03/20	LM8533616055500	EROS CHECK

Path 28 Row 47

	90/03/16	LM85220616325x0
	86/04/06	LM85076616375x0
29/47	76/03/28	LM8243116240500
30/47	76/03/20	LM8533616062500

Path 29 Row 39

	91/07/16	LE85269316384x0
	85/07/31	LM85051716451x0
31/39	73/07/05	LM8134716480500

Second WRS-1 not required?

Path 29 Row 40

	92/04/21	LE84356716204x0
	86/03/12	LM85074116415x0
31/40	75/03/18	LM8205516370500

Second WRS-1 not required?

Path 29 Row 41

	92/04/21	LE84356716211x0
	86/03/12	LM85074116421x0
31/41	73/12/14	LM8150916461500

Path 29 Row 42

	92/04/21	LE84356716213x0
	86/04/14	LM85077316420x0
31/42	76/09/08	LM8259516290500
32/42	76/05/06	LM8247016380500

Path 29 Row 43

	92/04/21	LE84356716220x0
	86/04/13	LM85077316422x0
30/43	73/07/22	LM8136416434500
31/43	72/08/15	LM8102316490500

Path 29 Row 44

	92/04/21	LE84356716222x0
	86/04/13	LM85077316424x0
30/44	73/03/18	LM8123816451500
31/44	76/03/21	LM8533716104500

Path 29 Row 45

	92/04/21	LE84356716224x0
	86/03/12	LM85074116435x0
30/45	76/03/20	LM8533616053500
31/45	76/03/21	LM8533716111500

Path 29 Row 46

	92/04/21	LE84356716231x0
	86/03/12	LM85074116441x0
30/46	76/03/20	LM8533616055500
31/46	73/02/11	LM8120316513500

Path 29 Row 47

	92/04/21	LE84356716233x0
	86/03/12	LM85074116444x0
30/47	76/03/20	LM8533616062500
31/47	72/12/19	LM8114916514500

Path 30 Row 40

	92/04/28	LE84357416271x0
	86/04/20	LM85078016471x0
32/40	75/06/17	LM821461642450O

Second WRS-1 not required?

Path 30 Row 41

	92/04/28	LE84357416273x0
	86/04/20	LM85078016473x0
32/41	73/03/02	LM8122216552500

Second WRS-1 not required?

Path 30 Row 42

	92/04/28	LE84357416275x0
	86/04/20	LM85078016480x0
32/42	76/05/06	LM8247016380500

Second WRS-1 not required?

Path 30 Row 43

	92/05/14	LE84359016290x0
	86/04/20	LM85078016482x0
32/43	76/05/06	LM8247016383500

Second WRS-1 not required?

Path 30 Row 44

	90/05/25	LM84287016535x0
	86/04/20	LM85078016485x0
32/44	73/03/02	LM8122216563500

Second WRS-1 not required?

Path 30 Row 45

	92/05/14	LE84359016295x0	Composite
	92/04/28	LE84357416291x0	
	86/04/20	LM85078016491x0	
32/45	73/03/02	LM8122216570500	

Second WRS-1 not required?

Path 30 Row 46

	92/05/30	LE84360616305x0	Composite
	92/05/14	LE84359016301x0	
	86/04/20	LM85078016493x0	
32/46	73/03/02	LM8122216572500	

Second WRS-1 not required?

Path 30 Row 47

DOUBLET

	85/05/19	LM85044416545x0
31/47	72/12/19	LM8114916514500
32/47	76/05/24	LM8248816394500

Path 31 Row 39

	92/06/30	LE85304316505x0
	86/06/14	LM85083516512x0
33/39	72/07/30	LM8100716590500

Second WRS-1 not required?

Path 31 Row 40

	92/05/21	LE84359716342x0
	87/06/17	LM85120316524x0
33/40	74/05/27	LM8167316532500

Second WRS-1 not required?

Path 31 Row 41

	92/05/21	LE84359716344x0
	85/05/10	LM85043516583x0
33/41	75/05/13	LM8211116484500

Second WRS-1 not required?

Path 31 Row 42

	92/04/19	LE84356516335x0
	85/05/10	LM85043516590x0
33/42	76/03/23	LM8533916211500

Second WRS-1 not required?

Path 31 Row 43

	92/05/05	LE84358116345x0	Composite
	92/04/19	LE84356516341x0	
	86/03/10	LM85073916552x0	
33/43	76/03/23	LM8533916214500	

Second WRS-1 not requied?

Path 31 Row 44

	92/05/05	LE84358116351x0	Composite
	92/04/19	LE84356516344x0	
	86/03/10	LM85073916555x0	
33/44	73/03/03	LM8122317022500	

Second WRS-1 not required?

Path 32 Row 38

	92/06/29	LE84363616405x0
	85/07/04	LM85049017033x0
34/38	75/06/28	LM8507016420500

Second WRS-1 not required?

Path 32 Row 39

	92/06/05	LE85301816572x0
	86/05/04	LM85079416585x0
34/39	73/06/02	LM8131417053500
35/39	73/06/03	LM8131517112500

Path 32 Row 40

	92/04/10	LE84355616385x0	
	86/04/18	LM85077816593x0	
34/40	73/06/02	LM8131417060500	
35/40	73/06/21	LM8133317113500	OR
	75/06/20	LM8214917000500	EROS CHECK

Path 32 Row 41

	92/04/10	LE84355616392x0
	86/04/02	LM85076217002x0
34/41	73/06/02	LM8131417062500
35/41	73/06/03	LM8131517121500

Path 32 Row 42

	92/04/10	LE84355616394x0
	86/04/02	LM85076217004x0
34/42	73/06/02	LM8131417065500
35/42	75/07/08	LM8216717004500

Path 32 Row 43

	92/04/10	LE84355616401x0
	84/04/04	LM84062817022x0
34/43	73/04/09	LM8126017074500
35/43	73/02/15	LM8120717131500

Path 33 Row 38

	92/06/04	LE84361116462x0
	86/07/30	LM85088117015x0
35/38	73/06/21	LM8133317104500
36/38	74/06/17	LM8169417090500

Path 33 Row 39

	92/04/01	LE84354716442x0
	86/03/24	LM85075317055x0
35/39	74/04/05	LM8162117054500
36/39	73/05/17	LM8129817171500

Path 33 Row 40

	92/04/01	LE84354716445x0
	86/03/24	LM85075317062x0
35/40	75/06/20	LM8214917000500
36/40	73/04/11	LM8126217175500

Path 33 Row 41

	92/04/01	LE84354716451x0
	86/03/24	LM85075317064x0
35/41	73/06/03	LM8131517121500
36/41	73/03/24	LM8124417182500

Path 33 Row 42

	92/05/03	LE84357916464x0
	86/03/24	LM85075317071x0
35/42	73/01/28	LM8118917123500
36/42	73/03/24	LM8124417184500

Path 33 Row 43

	92/06/04	LE84361116482x0
	86/03/24	LM85075317073x0
35/43	73/02/15	LM8120717131500

Second WRS-1 not required.

Path 33 Row 44

	92/05/03	LE84357916473x0
	86/03/24	LM85075317075x0
36/44	73/04/11	LM8126217193500

Second WRS-1 not required?

Path 34 Row 38

	92/06/11	LE85301617092x0
	86/05/18	LM85080817102x0
36/38	74/06/17	LM8169417090500
37/38	73/06/05	LM8131717222500

Path 34 Row 39

	92/06/11	LE84361816530x0
	83/06/03	LM84032217155x0
36/39	73/05/17	LM8129817171500
37/39	73/06/05	LM8131717224500

Path 34 Row 40

	92/06/11	LE84361816533x0
	83/06/03	LM84030617161x0
36/40	73/04/11	LM8126217175500
37/40	73/04/12	LM8126317234500

Path 34 Row 41

	92/04/24	LE84357016521x0
	86/03/15	LM85074417130x0
36/41	73/03/24	LM8124417182500
37/41	73/04/12	LM8126317240500

Path 34 Row 42

	92/04/24	LE84357016523x0
	86/03/15	LM85074417133x0
36/42	73/03/24	LM8124417184500
37/42	73/03/25	LM8124517243500

Path 34 Row 43

	92/04/24	LE84357016530x0
	86/03/15	LM85074417135x0
36/43	73/04/11	LM8126217191500
37/43	73/03/25	LM8124517245500

Path 34 Row 44

	92/04/24	LE84357016532x0
	86/03/15	LM85074417141x0
36/44	73/04/11	LM8126217193500

Path 35 Row 38

	92/06/02	LE84360916583x0
	86/06/10	LM85083117155x0
37/38	73/06/05	LM8131717222500
38/38	74/06/01	LM8167817210500

Path 35 Row 39

	92/06/02	LE84360916590x0
	83/04/23	LM84028117222x0
37/39	73/06/05	LM8131717224500
38/39	73/06/06	LM8131817283500

Path 35 Row 40

	92/05/01	LE84357716581x0
	83/04/23	LM84028117224x0
37/40	73/04/12	LM8126317234500
38/40	75/03/16	LM8196617111500

Path 35 Row 41

	92/05/01	LE84357716583x0
	83/04/23	LM84028117230x0
37/41	73/04/12	LM8126317240500
38/41	73/05/09	LM8130017293500

Path 35 Row 42

	92/05/01	LE84357716590x0
	86/04/23	LM85078317185x0
37/42	73/05/18	LM8129917241500
38/42	73/05/01	LM8128217301500

Path 35 Row 43

	92/05/01	LE84357716592x0
	86/04/23	LM85078317191x0
37/43	73/03/25	LM8124517245500
38/43	74/11/28	LM8185817170500

Path 36 Row 38

	92/10/07	LE85314217194x0
	86/09/05	LM85091817190x0
38/38	74/06/01	LM8167817210500
39/38	72/09/28	LM8106717330500

Path 36 Row 39

	92/05/08	LE84358417042x0
	83/04/14	LM84027217282x0
38/39	73/06/06	LM8131817283500
39/39	73/05/20	LM8130117342500

Path 36 Row 40

	92/05/08	LE84358417044x0
	83/04/14	LM84027217285x0
38/40	72/08/22	LM8103017280500
39/40	72/09/10	LM8104917340500

Path 36 Row 41

	92/05/24	LE84360017054x0
	87/07/22	LM85123817244x0
38/41	72/08/22	LM8103017283500
39/41	72/09/10	LM8104917342500

Path 36 Row 42

	92/05/24	LE84360017060x0
	87/07/22	LM85123817250x0
38/42	73/05/01	LM8128217301500

Second WRS-1 not required.

Path 37 Row 38

	92/10/14	LE85314917255x0
	86/10/14	LM85095717240x0
39/38	72/10/16	LM8108517332500
40/38	72/09/29	LM8106817385500

Path 37 Row 39

	92/05/31	LE84360717112x0
	87/07/13	LM85122917295x0
39/39	73/05/20	LM8130117342500
40/39	73/06/08	LM8132017395500

Path 37 Row 40

	92/05/15	LE84359117111x0
	83/05/07	LM84029517350x0
39/40	72/09/10	LM8104917340500
40/40	73/04/15	LM8126617405500

Path 37 Row 41

	92/04/29	LE84357517105x0
	86/04/21	LM85078117305x0
39/41	76/03/20	LM8242317191500
40/41	76/03/21	LM8242417245500

Path 38 Row 37

	92/08/02	LE85307617325x0	
	86/09/03	LM85091617310x0	
40/37	72/09/29	LM8106817382500	
41/37	72/09/30	LM8106917441500	

Path 38 Row 38

	92/07/17	LE85306017333x0	
	86/06/15	LM85083617341x0	
40/38	73/06/08	LM8132017393500	
41/38	73/07/15	LM8135717445500	

Path 38 Row 39

	92/04/20	LE84356617160x0	
	87/07/20	LM85123617361x0	
40/31	73/06/08	LM8132017395500	OR
	73/04/15	LM8126617402500	EROS CHECK
41/39	76/03/31	LM8534717052500	

Path 39 Row 40 To be selected

Path 39 Row 37

	92/06/30	LE84363717235x0	
	86/06/06	LM85082717402x0	
41/37	73/06/09	LM8132117445500	
42/37	73/05/23	LM8130417504500	

Path 39 Row 38

	92/06/30	LE84363717241x0
	86/05/05	LM85079517414x0
41/38	73/05/22	LM8130317453500
42/38	73/06/10	LM8132217510500

Path 39 Row 39

	DOUBLET	
	92/06/30	LE84363717244x0
41/39	76/06/11	LM8534717052500

Path 40 Row 37

	92/08/16	LE85309017450x0
	87/09/04	LM85128217490x0
42/37	72/09/13	LM8105217495500
43/37	73/09/27	LM8143117543500

Path 40 Row 38 To be selected

NALC MSS Triplicates - Hawaii

Path 62 Row 46

	No good 90's data.		
	No 80's data.		
67/46	73/02/11	LM8120320180500	

Path 62 Row 47

	90/07/28	LM84293420113x0	
	No 80's data.		
67/47	73/02/11	LM8120320182500	OR
	75/07/22	LM8218120061500	Check fiche

Path 63 Row 46

	92/07/24	LM84366119563x0	Composite with
	92/05/21	LM84359719542x0	
	No 1980's data.		
67/46	73/02/11	LM8120320180500	

Path 63 Row 47

	92/08/09	LM84367719572x0	Composite with
	92/07/24	LM84366119565x0	
	No 1980's data		
67/47	73/02/11	LM8120320182500	OR
	75/07/22	LM8218120061500	Check fiche

Path 64 Row 45

	92/07/15	LM84365220020x0	Composite with
	92/06/29	LM84363620013x0	
	No 1980's data		
68/45	73/01/25	LM8118620230500	

Path 64 Row 46

	92/07/15	LM84365220022x0
	No 1980's data	
68/46	LM	

Path 65 Row 45

92/08/07	LM84367520085x0	Composite 3 of 4?
92/07/22	LM84365920082x0	
92/07/06	LM84364320075x0	
92/06/20	LM84362720072x0	

Path 66 Row 45

92/07/29	LM84366620144x0	Composite with
92/06/27	LM84363420135x0	

No 1980's data

NALC MSS Triplicates - Alaska

Path 54 Row 21

	92/07/01	LM85304419055x0
	85/07/30	LM85051619123x0
59/21	74/09/02	LM8177119111500
60/21	73/07/16	LM8135819264500

Path 54 Row 22

	GLIS ALL 90's	
	85/07/30	LM85051619125x0
59/22	GLIS	
60/22	GLIS	

Path 55 Row 21

	GLIS ALL 90's	
	86/08/09	LM85089119104x0
60/21	73/07/16	LM8135819264500

Second WRS-1 not required?

Path 55 Row 22

	GLIS ALL 90's	
	86/09/26	LM85093919092x0
60/22	GLIS	

Second WRS-1 not required?

Path 56 Row 20

GLIS ALL 90's

	86/09/17	LM85093019150x0
61/20	74/09/22	LM8179119212500

Second WRS-1 not required?

Path 56 Row 21

GLIS ALL 90's

	86/09/17	LM85093019153x0
61/21	GLIS at 0-50% cloud level	

Second WRS-1 not required?

Path 57 Row 19

GLIS ALL 90's

86/06/04 OR
84/08/17

61/19	GLIS
62/19	GLIS 0-50%

Path 57 Row 20

GLIS ALL 90's

86/06/04 OR
86/10/10

61/20	GLIS 0-50%	
62/20	74/07/31	LM8173819291500

Path 57 Row 21

	GLIS ALL 90's		
	86/06/04	GLIS for ID	
61/21	GLIS 0-50%		
62/21	GLIS		

Path 58 Row 19

	92/06/27	LM85304019295x0	
	86/06/27	LM85084819295x0	
63/19	72/08/11	LM8101919430500	check fiche
64/19	GLIS 0-50%		

Path 58 Row 20

	92/06/27	LM85304019301x0
	86/09/15	LM85092819273x0
63/20	74/09/06	LM8177519333500

Second WRS-1 not required?

Path 59 Row 18

	GLIS ALL 90's	
	86/09/06	LM85091919331x0
64/18	72/08/12	LM8102019480500
65/18	GLIS	

Path 59 Row 19

	GLIS ALL 90's	
	86/09/06	LM85091919333x0
64/19	GLIS 0-50%	
65/19	72/09/18	LM8105719542500

Path 59 Row 20

	GLIS ALL 90's	
	86/09/06	GLIS for ID
64/20	GLIS	
65/20	GLIS	

Path 60 Row 19

	92/06/25	LM85303819421x0
	86/06/25	LM85084619422x0
65/19	72/09/18	LM8105719542500

Second WRS-1 not required?

Path 61 Row 18

	92/09/04	LM85310919470x0
	84/08/13	LM85016519542x0
66/18	73/07/22	LM8136419595500
67/18	73/07/23	LM8136520053500

Path 62 Row 17 To be selected

Path 62 Row 18

	92/08/10	LM85308419533x0
	86/09/11	LM85092419513x0
67/18	73/07/23	LM8136520053500
68/18	72/09/21	LM8106020111500

Path 63 Row 17

	GLIS ALL 90's	
	84/09/12	LM85019520065x0
68/17	GLIS	
69/17	74/07/02	LM8170920090500

Path 63 Row 18

	GLIS ALL 90's	
	84/09/12	LM85019520071x0
68/18	72/09/21	LM8106020111500
69/18	72/09/22	LM8106120165500

Path 64 Row 16

	GLISS ALL 90's		
	85/06/02	LM85045820123x0	
70/16	76/06/13	LM8250820042500	check fiche

Second WRS-1 not required?

Path 64 Row 17

GLIS ALL 90's

	85/06/02	LM85045820130x0	
70/17	74/06/15	LM8169220152500	check fiche

Second WRS-1 not required?

Path 64 Row 18

GLIS ALL 90's

	86/09/09	LM85092220040x0
70/18	73/09/18	LM8142220215500

Second WRS-1 not required?

Path 65 Row 15

	92/06/28	LM85304120113x0
	86/06/28	LM85084920113x0
71/15	72/09/24	LM8106320271500

Second WRS-1 not required?

Path 65 Row 16

	92/06/28	LM85304120115x0
	86/06/28	LM85084920120x0
71/16	75/07/08	LM8216720162500

Second WRS-1 not required?

Path 65 Row 17

	92/06/28	GLIS for ID
	86/06/28	LM85084920122x0
71/17	76/07/20	LM8254520093500

Second WRS-1 not required?

Path 65 Row 18

	92/06/12	LM85302520125x0
	86/06/28	GLIS for ID
71/18	76/06/14	LM8250920105500

Second WRS-1 not required?

Path 66 Row 14

	92/07/05	GLIS for ID
	86/07/05	LM85085620171x0
72/14	76/08/26	LM8258220125500
73/14	72/08/21	LM8102920381500

Path 66 Row 15

	92/07/05	LM85304820173x0	
	86/08/22	LM85090420155x0	OR
	86/09/07	LM85092020151x0	
72/15	76/08/26	LM8258220131500	
73/15	72/08/21	LM8102920383500	

Path 66 Row 16

	92/07/05	GLIS for ID
	86/07/05	LM85085620175x0
72/16	73/07/10	LM8135220333500

Second WRS-1 not required?

Path 66 Row 17

	92/07/05	LM85304820182x0
	86/07/05	LM85085620182x0
72/17	75/07/09	LM8216820223500

Second WRS-1 not required?

Path 66 Row 18

	92/07/05	GLIS for ID
	86/07/05 85/07/18	OR
72/18	75/07/09	GLIS for ID and X or N

Second WRS-1 not required?

Path 67 Row 13

	92/08/29	LM85310320221x0
	84/09/24	LM85020720295x0
73/13	76/08/27	LM8258320181500
74/13	76/07/23	LM8254820245500

Path 67 Row 14

	GLIS ALL 90's	
	84/09/24	LM85020720302x0
73/14	72/08/21	LM8102920381500
74/14	76/07/23	LM8254820252500

Path 67 Row 15

	92/08/28	LM85310020230x0
	86/09/14	LM85092720211x0
73/15	72/08/21	LM8102920383500
74/15	76/08/01	LM8547019553500

Path 67 Row 16

	92/06/10	LM85302320242x0
	86/09/14	LM85092720213x0
73/16	75/07/10	LM8216920275500
74/16	76/08/01	LM8547019560500

Path 67 Row 17

	92/06/10	LM85302320245x0
	86/07/28	LM85087920234x0
73/17	75/07/10	LM8216920281500

Second WRS-1 not required?

Path 67 Row 18

	92/08/29	LM85310320241x0	
	86/08/13	LM85089520233x0	OR
	86/07/28	LM85087920240x0	
73/18	75/07/09	GLIS for ID and X or N	

Second WRS-1 not required?

Path 68 Row 12

	92/06/01	LM85301420291x0	
	86/07/03	LM85085420284x0	OR
	86/06/01	LM85082220294x0	
74/12	72/08/22	LM8103020430500	
75/12	76/07/06	LM8253120304500	

Path 68 Row 13

	92/07/03	LM85304620291x0	
	86/07/03	LM85085420291x0	OR
	85/08/01	LM85051820355x0	
74/13	76/07/23	LM8254820245500	
75/13	76/08/11	LM8256720300500	

Path 68 Row 14

	92/07/03	LM85304620293x0
	85/08/01	LM85051820361x0
74/14	76/07/23	LM8254820252500
75/14	76/07/06	LM8253120313500

Path 68 Row 15

	92/07/03	LM85304620295x0	
	86/09/05	LM85091820274x0	
74/15	76/08/01	LM8547019553500	
75/15	76/07/06	LM8253120320500	

Path 68 Row 16

	92/07/03	LM85304620302x0	
	86/07/03	LM85085420302x0	OR
	86/09/05	LM85091820280x0	
74/16	76/08/01	LM8547019560500	
75/16	76/07/06	LM8253120322500	

Path 68 Row 17

	92/07/03	LM85304620304x0	
	86/09/05	LM85091820282x0	
74/17	75/07/11	LM8217020340500	
75/17	76/07/06	LM8253120325500	

Path 68 Row 18

	92/07/03	LM85304620311x0	
	86/09/05	LM85091820285x0	OR
	84/08/14	LM85016620374x0	
74/18	73/08/17	LM8139020452500	

Path 69 Row 11

	GLIS ALL 90's	
	85/07/07	LM85049320412x0
76/11	74/06/21	LM8169820470500

Second WRS-1 not required?

Path 69 Row 12

	GLIS ALL 90's	
	85/07/07	LM85049320414x0
76/12	74/09/01	LM8177020450500

Second WRS-1 not required?

Path 69 Row 13

	92/09/04	LM84370320214x0
	84/09/22	LM85020520422x0
75/13	76/08/11	LM8256720300500
76/13	75/08/18	LM8220820425500

Path 69 Row 14

	92/09/04	LM84370320220x0	
	84/09/22	LM85020520424x0	
75/14	76/07/06	LM8253120313500	
76/14	76/09/17	LM8260420351500	check fiche

Path 69 Row 15

	92/09/04	LM84370320223x0	
	84/09/22	LM85020520430x0	
75/15	76/07/06	LM8253120320500	
76/15	GLIS 0-50%		

Path 69 Row 16

	92/06/08	LM85302120365x0	
	84/06/18	LM85010920414x0	
75/16	76/07/06	LM8253120322500	
76/16	74/07/27	LM8173420480500	

Path 69 Row 17

	92/09/12	LM85311720355x0	
	86/09/12	LM85092520342x0	check fiche
75/17	76/07/06	LM8253120325500	
76/17	74/07/27	LM8173420482500	

Path 69 Row 18

	92/06/08	LM85302120374x0	
	84/06/18	LM85010920423x0	
75/18	GLIS 0-50%		

Second WRS-1 not required?

Path 69 Row 19

GLIS ALL 90's

86/07/26 LM85087720365x0

75/19 GLIS 0-50%

Second WRS-1 not required?

Path 69 Row 20

GLIS ALL 90's

86/07/26 LM85087720372x0

75/20 74/09/18 LM8178720415500

Second WRS-1 not required?

Path 70 Row 11

92/07/17 LM85306020403x0

86/07/01 LM85085220404x0

77/11 73/08/02 LM8137520595500

Second WRS-1 not required?

Path 70 Row 12

92/07/17 LM85306020405x0

86/07/01 LM85085220411x0

77/12 73/08/02 LM8137521002500

Second WRS-1 not required?

Path 70 Row 13

	92/07/17	LM85306020412x0	
	86/07/17	LM85086820410x0	check fiche
76/13	75/08/18	LM8220820425500	
77/13	76/09/18	LM8260520403500	

Path 70 Row 14

	92/07/01	LM85304420415x0
	84/08/12	LM85016420483x0
76/14	76/09/17	LM8260420351500
77/14	74/09/02	LM8177120513500

Path 70 Row 15

	92/08/02	LM85307620415x0
	84/08/12	LM85016420485x0
76/15	76/06/01	LM8249620384500
77/15	74/09/02	LM8177120515500

Path 70 Row 16

	GLIS ALL 90's	
	86/07/01	LM85085220424x0
76/16	74/07/27	LM8173420480500
77/16	72/08/25	LM8103321020500

Path 70 Row 17

	92/09/03	LM85310820421x0
	85/09/16	LM85056420491x0
76/17	74/07/27	LM8173420482500
77/17	72/08/25	LM8103321022500

Path 70 Row 18

	GLIS ALL 90's	
	85/09/16	LM85056420493x0
76/18	GLIS 0-50%	
77/18	72/08/25	LM8103321025500

Path 70 Row 19

	92/06/07	LM84361420273x0
	84/08/12	LM85016420502x0
76/19	74/07/27	LM8173420491500

Second WRS-1 not required?

Path 70 Row 20

	GLIS ALL 90's	
	84/08/12	LM85016420505x0
76/20	74/07/27	LM8173420494500

Second WRS-1 not required?

Path 71 Row 11

	92/06/30	LM84363720311x0
	86/07/08	LM85085920464x0
78/11	76/08/14	LM8257020462500

Second WRS-1 not required?

Path 71 Row 12

	92/08/01	LM84366920324x0	Composite with
	92/07/16	LM84365320321x0	
	86/07/08	LM85085920471x0	
78/12	GLIS 0-50%		

Second WRS-1 not required?

Path 71 Row 13

	92/08/01	LM84366920330x0
	85/07/21	LM85050720542x0
77/13	76/09/18	LM8260520403500
78/13	74/09/03	LM8177220565500

Path 71 Row 14

	92/08/01	LM84366920332x0
	85/07/21	LM85050720545x0
77/14	74/09/02	LM8177120513500
78/14	75/09/25	LM8224620542500

Path 71 Row 15

	92/08/01	LM84366920335x0
	85/07/21	LM85050720551x0
77/15	74/09/02	LM8177120515500
78/15	74/09/03	LM8177220574500

Path 71 Row 16

	GLIS ALL 90's	
	85/07/05	LM85049120554x0
77/16	72/08/25	LM8103321020500
78/16	73/07/16	LM8135821075500

Path 71 Row 17

	GLIS ALL 90's	
	84/09/04	LM85018720561x0
77/17	72/08/25	LM8103321022500
78/17	74/09/03	LM8177220583500

Path 71 Row 18

	92/06/30	LM84363720340x0	
	GLIS 80's		
77/18	76/06/20	LM8251520451500	CHECK FICHE
78/17	73/07/16	LM8135821082500	

Path 71 Row 19

	GLIS ALL 90's	
	85/07/05	LM85049120565x0
77/19	76/07/08	LM8253320450500
78/19	76/07/09	LM8253420504500

Path 71 Row 20

	GLIS ALL 90's	
	84/09/04	LM85018720572x0
77/20	76/07/08	LM8253320453500
78/20	76/07/09	LM8253420511500

Path 72 Row 11

	92/07/23	LM84366020381x0
	86/07/15	LM85086620524x0
79/11	74/09/04	LM8177321014500

Second WRS-1 not required?

Path 72 Row 12

	92/06/05	LM84361220370x0
	85/06/10	LM85046621002x0
79/12	GLIS 0-50%	

Second WRS-1 not required?

Path 72 Row 13

	92/06/05	LM84361220372x0
	86/06/13	LM85083420543x0
79/13	73/06/29	LM8134121123500

Second WRS-1 not required?

Path 72 Row 14

	92/06/05	LM84361220375x0
	86/06/13	LM85083420545x0
78/14	75/09/25	LM8224620542500
79/14	73/06/29	LM8134121130500

Path 72 Row 15

	GLIS ALL 90's	
	86/06/13	LM85083420552x0
78/15	73/07/16	LM8135821073500
79/15	73/06/29	LM8134121132500

Path 72 Row 16

	92/06/05	LM84361220383x0
	86/06/13	LM85083420554x0
78/16	73/07/16	LM8135821075500
79/16	73/06/29	LM8134121135500

Path 72 Row 17

	92/06/05	LM84361220390x0
	86/06/13	LM85083420560x0
78/17	73/07/16	LM8135821082500
79/17	73/06/29	LM8134121141500

Path 72 Row 18

	GLIS ALL 90's	
	86/05/28	LM85081820570x0
78/18	76/07/09	LM8253420502500
79/18	76/07/10	LM8253520560500

Path 72 Row 19

	GLIS ALL 90's	
	86/05/28	LM85081820572x0
78/19	76/07/09	LM8253420504500
79/19	GLIS 0-50%	

Path 72 Row 20

	GLIS ALL 90's	
	86/05/28	LM85081820575x0
78/20	76/07/09	LM8253420511500
79/20	74/07/30	LM8173721064500

Path 72 Row 21 To be Selected

Path 73 Row 11

	92/08/31	LM84369920453x0
	85/08/04	LM85052121055x0
80/11	74/06/25	LM8170221095500
81/11	76/07/12	LM8253721043500

Path 73 Row 12

	GLIS ALL 90's	
	85/08/04	LM85052121061x0
80/12	74/09/05	LM8177421074500

Second WRS-1 not required?

Path 73 Row 13

	GLIS ALL 90's	
	86/08/23	LM85090520581x0
80/13	73/06/30	LM8134221182500

Second WRS-1 not required?

Path 73 Row 14

	GLIS ALL 90's	
	85/07/19	LM85050521071x0
79/14	73/06/29	LM8134121130500
80/14	76/07/11	LM8253621000500

Path 73 Row 15

	GLIS ALL 90's	
	84/09/02	LM85018521074x0
79/15	74/09/04	LM8177321032500
80/15	75/09/09	LM8223021063500

Path 73 Row 16

	GLIS ALL 90's	
	84/09/02	LM85018521081x0
79/16	74/09/04	LM8177321034500
80/16	72/08/10	LM8101821191500

Path 73 Row 17

	GLIS ALL 90's	
	84/09/02	LM85018521083x0
79/17	73/06/29	LM8134121141500
80/17	72/08/10	LM8101821193500

Path 73 Row 18

	GLIS ALL 90's	
	84/09/02	LM85018521090x0
79/18	76/07/10	LM8253520560500
80/18	74/08/18	LM8175621110500

Path 73 Row 19

	GLIS ALL 90's	
	84/09/02	LM85018521092x0
79/19	GLIS 0-50%	
80/19	GLIS 0-50%	

Path 73 Row 20

	GLIS ALL 90's	
	84/09/02	LM85018521094x0
79/20	74/07/30	LM8173721064500
80/20	72/09/15	LM8105421205500

Path 73 Row 21

	GLIS ALL 90's	
	84/09/02	LM85018521101x0
79/21	GLIS 0-50%	
80/21	GLIS 0-50%	

Path 74 Row 10

	GLIS ALL 90's	
	85/08/27	LM85054421112x0
81/10	74/09/06	LM8177521124500
82/10	GLIS	

Path 74 Row 11

	GLIS ALL 90's	
	85/08/27	LM85054421115x0
81/11	76/07/12	LM8253721043500
82/11	GLIS	

Path 74 Row 12

	92/09/07	LM84370620521x0
	85/07/26	LM85051221123x0
81/12	74/09/06	LM8177521133500
82/12	GLIS	

Path 74 Row 13

	92/09/07	LM84370620524x0
	85/07/26	LM85051221125x0
81/13	76/07/12	LM8253721052500

Second WRS-1 not required?

Path 74 Row 14

	92/09/07	LM84370620530x0
	85/07/26	LM85051221132x0
81/14	76/07/12	LM8253721055500

Second WRS-1 not required?

Path 74 Row 15

	92/09/07	LM84370620533x0
	85/07/26	LM85051221134x0
81/15	72/08/29	LM8103721243500

Second WRS-1 not required?

Path 74 Row 16

	92/09/07	LM84370620535x0
	85/07/26	LM85051221141x0
80/16	72/08/10	LM8101821191500
81/16	75/09/28	LM8224921123500

Path 74 Row 17

	92/06/03	LM84361020512x0
	86/05/26	LM85081621090x0
80/17	72/08/10	LM8101821193500
81/17	GLIS 0-50%	

Path 74 Row 18

	GLIS ALL 90's	
	86/05/26	LM85081621092x0
80/18	74/08/18	LM8175621110500
81/18	75/08/05	LM8219521140500

Path 74 Row 19

	92/08/06	LM84367420541x0
	GLIS 80's	
80/19	74/08/18	GLIS for ID and X or N
81/19	75/08/05	LM8219521142500

Path 74 Row 21 To be selected

Path 74 Row 22 To be selected

Path 75 Row 10

	GLIS ALL 90's	
	86/07/04	LM85085521111x0
82/10	GLIS	
83/10	74/07/16	LM8172321260500

Path 75 Row 11

	92/07/28	LM84366520565x0
	85/08/02	LM85051921181x0
82/11	GLIS	
83/11	74/07/16	LM8172321262500

Path 75 Row 12

	92/07/28	LM84366520571x0	
	85/07/17	LM85050321184x0	
82/12	GLIS		
83/12	76/08/01	LM8255721155500	check fiche

Path 75 Row 13

	GLIS ALL 90's	
	86/07/04	LM85085521122x0
82/13	GLIS	

Second WRS-1 not required?

Path 75 Row 14

	92/07/12	LM84364920573x0
	86/07/04	LM85085521124x0
82/14	GLIS	

Second WRS-1 not required?

Path 75 Row 15

	92/07/28	LM84366520582x0	Composite with
	92/07/12	LM84364920575x0	
	85/08/02	LM85051921195x0	
82/15	GLIS		

Second WRS-1 not required?

Path 75 Row 16

GLIS ALL 90's

85/08/02 LM85051921201x0

82/16 GLIS

Second WRS-1 not required?

Path 75 Row 17

GLIS ALL 90's

85/08/02 LM85051921204x0

81/17 GLIS 0-50%

82/17 GLIS

Path 75 Row 18

GLIS ALL 90's

85/08/02 LM85051921210x0

81/18 75/08/05 LM8219521140500

82/18 GLIS

Path 75 Row 19

GLIS ALL 90's

84/09/16 LM85019921214x0

81/19 76/09/04 LM8259121062500 check fiche

82/19 GLIS

Path 75 Row 22 To be selected

Path 76 Row 10

	GLIS ALL 90's		
	86/08/12	LM85089421160x0	
83/10	74/07/16	LM8172321260500	
84/10	74/08/22	LM8176021302500	

Path 76 Row 11

	92/06/17	LM84362421014x0	
	84/09/23	LM85020621244x0	
83/11	74/07/16	LM8172321262500	
84/11	74/08/22	LM8176021305500	

Path 76 Row 12

	GLIS ALL 90's		
	86/09/13	LM85092621154x0	
83/12	74/09/08	LM8177721245500	
84/12	72/09/19	LM8105821403500	check fiche

Path 76 Row 13

	GLIS ALL 90's		
	84/06/03	LM85009421233x0	
83/13	74/08/03	LM8174121264500	
84/13	75/07/21	LM8218021293500	

Path 76 Row 14

	GLIS ALL 90's	
	84/08/06	LM85015821252x0
83/14	74/08/03	LM8174121270500

Second WRS-1 not required?

Path 76 Row 15

	GLIS ALL 90's		
	85/05/21	LM85044621262x0	OR
	84/06/03	LM85009421242x0	
83/15	76/08/19	LM8257521163500	

Second WRS-1 not required?

Path 76 Row 16

	92/06/17	LM84362421034x0
	85/07/24	LM85051021263x0
83/16	76/08/19	LM8257521170500

Second WRS-1 not required?

Path 76 Row 17

	92/06/17	LM84362421040x0
	85/07/24	LM85051021265x0
82/17	GLIS	
83/17	75/06/14	LM8214321254500

Path 76 Row 18

	GLIS ALL 90's	
	84/06/03	LM85009421253x0
82/18	GLIS	
83/18	GLIS 0-50%	

Path 76 Row 19

	GLIS ALL 90's	
	84/06/03	LM85009421255x0
81/19	75/08/05	LM8219521142500
82/19	GLIS	

Path 76 Row 22 To be selected

Path 77 Row 10

	GLIS ALL 90's	
	84/06/26	LM85011721285x0
84/10	74/08/22	LM8176021302500
85/10	73/06/17	LM8132921455500

Path 77 Row 11

	GLIS ALL 90's	
	84/08/29	LM85018121305x0
84/11	74/08/22	LM8176021305500
85/11	75/07/22	LM8218121342500

Path 77 Row 12

	92/09/28	LM84372721112x0	
	84/08/29	LM85018121311x0	
84/12	72/09/19	LM8105821403500	check fiche
85/12	73/06/17	LM8132921464500	

Path 77 Row 13

	92/09/28	LM84372721114x0
	86/07/02	LM85085321245x0
84/13	75/07/21	LM8218021293500
85/13	75/07/22	LM8218121351500

Path 77 Row 14

GLIS ALL 90's

	86/07/02	LM85085321251x0
84/14	75/07/03	LM8216221301500

Second WRS-1 not required?

Path 77 Row 15

GLIS ALL 90's

	86/07/02	LM85085321253x0
84/15	75/07/03	LM8216221304500

Second WRS-1 not required?

Path 77 Row 16

	GLIS ALL 90's	
	86/07/02	LM85085321260x0
84/16	76/06/27	LM8252221242500

Second WRS-1 not required?

Path 77 Row 17

	GLIS ALL 90's	
	84/08/29	LM85018121331x0
84/17	75/07/21	LM8218021311500

Second WRS-1 not required?

Path 77 Row 18

	92/06/24	LM84363121105x0
	84/06/26	LM85011721320x0
84/18	75/08/08	LM8219821311500

Second WRS-1 not required?

Path 77 Row 23 To be selected

Path 78 Row 10

	GLIS ALL 90's	
	84/07/03	LM85012421351x0
85/10	73/06/17	LM8132921455500
86/10	GLIS	

Path 78 Row 11

	92/06/15	LM84362221140x0
	84/07/03	LM85012421353x0
85/11	73/06/17	LM8132921462500
86/11	GLIS	

Path 78 Row 12

	GLIS ALL 90's	
	85/07/06	LM85049221372x0
85/12	73/06/17	LM8132921464500
86/12	GLIS	

Path 78 Row 13

	92/09/03	LM84370221172x0
	85/07/06	LM85049221374x0
85/13	75/07/22	LM8218121351500
86/13	GLIS	

Path 78 Row 14

	GLIS ALL 90's	
	85/07/22	LM85050821380x0
85/14	75/07/04	LM8216321355500
86/14	GLIS	

Path 78 Row 15

GLIS ALL 90's

84/06/17 LM85010821365x0

85/15 73/06/17 GLIS for ID and X or N

Second WRS-1 not required?

Path 78 Row 16

GLIS ALL 90's

84/06/17 LM85010821372x0

85/16 76/06/10 LM8250521303500

Second WRS-1 not required?

Path 78 Row 17

GLIS ALL 90's

84/06/01 LM85009221373x0

85/17 76/06/10 LM8250521305500

Second WRS-1 not required?

Path 78 Row 18

GLIS ALL 90's

84/06/01 LM85009221375x0

85/18 76/06/10 LM8250521312500

Second WRS-1 not required?

Path 78 Row 23 To be selected

Path 79 Row 10

	GLIS ALL 90's	
	86/06/30	LM85085121360x0
86/10	GLIS	
87/10	75/07/06	LM8216521454500

Path 79 Row 11

	92/07/08	LM84364521205x0
	86/06/14	LM85083521365x0
86/11	GLIS	
87/11	75/07/06	LM8216521461500

Path 79 Row 12

	92/06/06	LM84361321202x0
	86/06/14	LM85083521372x0
86/12	GLIS	
87/12	75/07/06	LM8216521463500

Path 79 Row 13

	92/06/06	LM84361321204x0
	86/06/14	LM85083521374x0
86/13	GLIS	
87/13	74/07/02	LM8170921504500

Path 79 Row 14

	92/06/06	LM84361321210x0	
	86/06/30	LM85085121374x0	
86/14	GLIS		
87/14	74/07/02	LM8170921510500	

Path 79 Row 15

	92/06/06	LM84361321213x0	
	86/06/30	LM85085121380x0	
86/15	GLIS		
87/15	74/07/02	LM8170921513500	check X or N

Path 79 Row 16

	92/06/06	LM84361321215x0	
	84/08/27	LM85017921451x0	
86/16	GLIS		

Second WRS-1 not required?

Path 79 Row 17

	92/09/26	LM84372521254x0	
	84/09/28	LM85021121454x0	
86/17	GLIS		

Second WRS-1 not required?

Path 79 Row 18

	GLIS ALL 90's	
	84/09/28	LM85021121460x0
86/18	GLIS	

Second WRS-1 not required?

Path 80 Row 10

	92/07/15	LM84365221265x0
	84/07/01	LM85012221473x0
87/10	75/07/06	LM8216521454500
88/10	76/08/06	LM8256221433500

Path 80 Row 11

	92/07/15	LM84365221272x0
	86/07/07	LM85085821422x0
87/11	75/07/06	LM8216521461500
88/11	74/07/03	LM8171021553500

Path 80 Row 12

	92/07/31	LM84366821281x0
	86/07/07	LM85085821424x0
87/12	75/07/06	LM8216521463500
88/12	GLIS 0-50%	

Path 80 Row 13

	92/07/31	LM84366821284x0	
	84/07/01	LM85012221484x0	
87/13	74/07/02	LM8170921504500	
88/13	75/07/25	LM8218421522500	

Path 80 Row 14

	92/07/31	LM84366821290x0	
	84/07/01	LM85012221490x0	
87/14	74/07/02	LM8170921510500	
88/14	74/07/03	LM8171021565500	

Path 80 Row 15

	92/07/31	LM84366821292x0	
	84/07/01	LM85012221493x0	
87/15	74/07/02	LM8170921513500	check X or N
88/15	74/07/03	LM8171021571500	

Path 81 Row 10

	92/07/06	LM84364321325x0	
	GLIS		
89/10	76/08/25	LM8258121484500	

Second WRS-1 not required?

Path 81 Row 11

	92/07/06	LM84364321331x0
	84/06/06	LM85009721534x0
89/11	72/08/01	LM8100922083500

Second WRS-1 not required?

Path 81 Row 12

	92/07/06	LM84364321334x0
	84/06/06	LM85009721540x0
88/12	GLIS 0-50%	
89/12	72/08/01	LM8100922090500

Path 81 Row 13

	92/06/20	LM84362721333x0
	84/06/06	GLIS for ID
88/13	75/07/25	LM8218421522500
89/13	72/08/01	LM8100922092500

Path 81 Row 14

	92/07/06 92/07/22	LM84364321334x0 LM84365921345x0	Composite with
	84/06/06	GLIS for ID	
88/14	74/07/03	LM8171021565500	
89/14	72/08/01	LM8100922095500	

Path 81 Row 15

	GLIS ALL 90's	
	84/06/06	GLIS for ID
88/15	74/07/03	LM8171021571500

Second WRS-1 not required?

Path 82 Row 10

	GLIS ALL 90's	
	84/09/01	LM85018422012x0
90/10	72/08/02	LM8101022135500

Second WRS-1 not required?

Path 82 Row 11

	92/07/29	LM4366621401x0
	84/06/29	LM85012022001x0
90/11	75/08/14	LM8220422022500

Second WRS-1 not required?

Path 82 Row 12

	92/07/29	LM84366621403x0
	84/06/29	LM85012022004x0
89/12	72/08/01	LM8100922090500
90/12	72/08/02	LM8101022144500

Path 82 Row 13

	92/07/13	LM84365021402x0
	84/07/15	LM85013622011x0
89/12	72/08/01	LM8100922090500
90/12	72/08/02	LM8101022144500

Path 82 Row 14

	92/07/29	LM84366621412x0	Composite with
	92/07/13	LM84365021405x0	
	84/07/15	LM85013622014x0	
89/14	72/08/01	LM8100922095500	
90/14	72/08/02	LM8101022153500	

Path 83 Row 12

	92/07/04	LM84364121455x0
	84/09/08	LM85019122082x0
90/12	72/08/02	LM8101022144500
91/12	73/06/23	LM8133522210500

Path 83 Row 13

GLIS ALL 90's

	84/09/08	LM85019122085x0
90/13	74/08/10	LM8174822063500

Second WRS-1 not required?

Path 83 Row 14

	GLIS ALL 90's	
	84/06/04	LM85009522071x0
90/14	72/08/02	LM8101022153500

NALC MSS Triplicates - Western USA

Path 33 Row 33

	92/07/06	LM84364316452x0
	86/07/30	LM85088116595x0
35/33	74/07/04	LM8171117004500
36/33	75/06/30	LM8507216511500

Path 33 Row 34

	92/07/06	LM84364316454x0
	86/06/28	LM85084917012x0
35/34	74/07/04	LM8171117010500
36/34	75/06/30	LM8507216514500

Path 33 Row 35

	92/07/06	LM84364316461x0
	86/06/12	LM85083317021x0
35/35	75/06/29	LM8507116462500
36/35	74/06/17	LM8169417074500

Path 33 Row 36

	92/08/07	LM84367516473x0
	86/07/30	LM85088117010x0
35/36	74/07/04	LM8171117015500
36/36	72/08/02	LM8101017145500

Path 33 Row 37			
	92/08/07	LM84367516475x0	
	86/07/30	LM85088117013x0	
35/37	73/06/21	LM8133317102500	
36/37	72/08/02	LM8101017152500	
Path 34 Row 31			
	92/07/21 92/07/05	LM85306417055x0 LM84304817061x0	Composite with
	85/07/02	LM85048817130x0	
36/31	74/07/23	LM8173017045500	fiche missing
37/31	75/07/01	LM8507316561500	
Path 34 Row 32			
	92/07/05	LM85304817063x0	
	85/06/16	LM85047217133x0	
36/32	73/07/10	LM8135217134500	
37/32	75/07/01	LM8507316563500	
Path 34 Row 33			
	92/07/05	LM85304817065x0	
	83/07/05	LM84035417134x0	
36/33	75/06/30	LM8507216511500	
37/33	75/07/01	LM8507316570500	

Path 34 Row 34

	92/07/05	LM85304817072x0
	83/07/05	LM84035417140x0
36/34	75/06/30	LM8507216514500
37/34	75/07/01	LM8507316572500

Path 34 Row 35

	92/09/07	LM85311217065x0
	86/08/22	LM85090417060x0
36/35	75/09/19	LM8224017022500
37/35	73/09/21	LM8142517193500

Path 34 Row 36

	92/09/07	LM85311217071x0
	86/08/22	LM85090417062x0
36/36	72/08/02	LM8101017145500
37/36	73/08/16	LM8138917204500

Path 34 Row 37

	92/07/05	LM85304817083x0
	85/07/02	LM85048817152x0
36/37	73/06/22	LM8133417160500
37/37	75/06/22	LM8215117101500

Path 35 Row 31

	92/06/02	LM84360916555x0
	85/06/07	LM85046317192x0
37/31	75/07/01	LM8507316561500
38/31	73/06/06	LM8131817251500

Path 35 Row 32

	92/08/13	LM85308717121x0
	86/07/28	LM85087917115x0
37/32	74/08/11	LM8174917102500 OR (Fiche missing)
	75/07/01	LM8507316563500
38/32	74/08/30	LM8176817152500

Path 35 Row 33

	92/06/18	LM84362516570x0
	86/07/28	LM85087917122x0
37/33	75/07/01	LM8507316570500
38/33	73/06/06	LM8131817260500

Path 35 Row 34

	92/06/18	LM84362516572x0
	85/06/23	LM85046317203x0
37/34	75/07/01	LM8507316572500
38/34	75/06/05	LM8213417143500

Path 35 Row 35

	92/06/18	LM84362516575x0
	85/06/23	LM85047917205x0
37/35	73/06/05	LM8131717210500
38/35	73/06/06	LM8131817265500

Path 35 Row 36

	92/06/02	LM84360916575x0
	85/07/09	LM85049517211x0
37/36	73/06/05	LM8131717213500
38/36	75/06/05	LM8213417152500

Path 35 Row 37

	92/06/02	LM84360916581x0
	86/06/10	LM85083117153x0
37/37	73/06/05	LM8131717215500
38/37	74/06/01	LM8167817203500

Path 36 Row 29

	92/07/27	LM84366417025x0
	86/07/19	LM85087017171x0
38/29	74/07/25	LM8173217153500
39/29	74/07/26	LM8173317211500

Path 36 Row 30

	92/07/27	LM84366417032x0	
	86/07/19	LM85087017173x0	
38/30	73/07/30	LM8137217240500	
39/30	72/08/05	LM8101317294500	

Path 36 Row 31

	92/08/12	LM84368017041x0	
	86/08/17	LM85053417250x0	
38/31	74/07/25	LM8173217162500	fiche missing
39/31	72/08/05	LM8101317300500	

Path 36 Row 32

	92/08/28	LM84369617050x0	
	85/08/17	LM85053417252x0	
38/32	74/08/30	LM8176817152500	
39/32	73/09/05	LM8140917300500	

Path 36 Row 33

	92/08/20	LM85309417184x0	
	86/08/04	LM85088617181x0	
38/33	73/09/04	LM8140817244500	
39/33	73/09/05	LM8140917303500	

Path 36 Row 34

	92/08/28	LM84369617055x0	
	86/09/05	LM85091817172x0	
38/34	73/09/04	LM8140817251500	fiche missing
39/34	74/08/31	LM8176917215500	

Path 36 Row 35

	92/09/05	LM85311017191x0	
	86/09/05	LM85091817175x0	
38/35	73/09/04	LM8140817253500	
39/35	72/09/10	LM8104917315500	

Path 36 Row 36

	92/07/19	LM85306217202x0	
	85/06/30	LM85048617272x0	
38/36	74/07/25	LM8173217182500	fiche missing
39/36	75/06/24	LM8215317211500	

Path 36 Row 37

	92/07/19	LM85306217204x0	
	85/06/14	LM85047017275x0	
38/37	75/06/23	LM8215217155500	
39/37	73/06/25	LM8133717332500	

Path 37 Row 29

	92/08/19	LM84368717095x0
	86/08/27	LM85090917220x0
39/29	72/09/05	LM8140917285500
40/29	73/08/01	LM8137417351500

Path 37 Row 30

	92/08/27	LM85310117233x0
	86/08/27	LM85090917222x0
39/30	72/08/05	LM8101317294500
40/30	72/08/06	LM8101417352500

Path 37 Row 31

	92/07/26	LM85306917242x0
	85/08/08	LM85052517312x0
39/31	72/08/05	LM8101317300500
40/31	72/08/06	LM8101417355500

Path 37 Row 32

	92/07/26	LM85306917245x0
	85/08/08	LM85052517312x0
39/32	73/09/05	LM8140917300500
40/32	72/08/06	LM8101417361500

Path 37 Row 33

	92/08/27	LM85310117244x0
	85/08/24	LM85054117315x0
39/33	73/09/05	LM8140917303500
40/33	72/08/06	LM8101417364500

Path 37 Row 34

	92/08/27	LM85310117251x0
	85/08/24	LM85054117322x0
39/34	74/08/31	LM8176917215500
40/34	72/08/06	LM8101417370500

Path 37 Row 35

	92/08/27	LM85310117253x0
	85/08/24	LM85054117324x0
39/35	72/09/10	LM8104917315500
40/35	72/08/24	LM8103217373500

Path 37 Row 36

	92/08/27	LM85310117255x0
	86/07/26	LM85087717255x0
39/36	72/08/23	LM8103117322500
40/36	72/08/24	LM8103217375500

Path 37 Row 37

	92/07/26	LM85306917265x0
	86/07/26	LM85087717262x0
39/37	73/06/25	LM8133717332500
40/37	75/07/31	LM8219017265500

Path 38 Row 27

	92/08/02	LM85307617285x0
	86/08/02	LM85088417281x0
40/27	73/08/01	LM8137417342500
41/27	72/08/25	LM8103317400500

Path 38 Row 28

	92/07/17	LM85306017293x0
	86/08/02	LM85088417284x0
40/28	73/08/01	LM8137417344500
41/28	75/08/10	LM8511317152500

Path 38 Row 29

	92/08/26	LM84369417161x0
	86/08/02	LM85088417290x0
40/29	73/08/01	LM8137417351500
41/29	72/08/07	LM8101517404500

Path 38 Row 30

	92/08/26	LM84369417163x0
	85/08/15	LM85053217370x0
40/30	72/08/06	LM8101417352500
41/30	72/08/07	LM8101517410500

Path 38 Row 31

	92/07/17	LM85306017304x0
	86/08/02	LM85088417295x0
40/31	72/08/06	LM8101417355500
41/31	72/08/07	LM8101517413500

Path 38 Row 32

	92/07/17	LM85306017311x0
	86/08/02	LM85088417301x0
40/32	72/08/06	LM8101417361500
41/32	72/08/07	LM8101517415500

Path 38 Row 33

	92/08/26	LM84369417174x0
	85/08/15	LM85053217381x0
40/33	72/08/06	LM8101417364500
41/33	72/08/07	LM8101517422500

Path 38 Row 34

	92/08/18	LM85309217312x0
	86/08/02	LM85088417310x0
40/34	72/08/06	LM8101417370500
41/34	72/08/07	LM8101517424500

Path 38 Row 35

	92/07/01	LM85304417323x0
	86/07/17	LM85086817320x0
40/35	74/07/09	LM8171617300500
41/35	74/06/22	LM8169917362500

Path 38 Row 36

	92/08/02	LM85307617323x0
	85/08/15	LM85053217392x0
40/36	72/08/24	LM8103217375500
41/36	72/08/07	LM8101517433500

Path 39 Row 27

	91/07/06	LM85268317353x0
	85/06/19	LM85047517422x0
42/27	74/06/23	LM8170017384500

Second WRS-1 not required?

Path 39 Row 28

	91/07/22	LM85269917361x0
	85/07/21	LM85050717424x0
42/28	73/07/16	LM8135817462500

Second WRS-1 not required?

Path 39 Row 29

	92/08/09	LM85308317355x0
	85/07/05	LM85049117431x0
42/29	75/08/11	LM8511417213500

Second WRS-1 not required?

Path 39 Row 30

	92/07/16	LM84365317213x0
	85/07/05	LM85049117433x0
41/30	72/08/07	LM8101517410500
42/30	73/07/16	LM8135817471500

Path 39 Row 31

	92/07/16	LM84365317215x0
	86/06/22	LM85084317372x0
41/31	74/06/22	LM8169917344500
42/31	74/06/23	LM8170017402500

Path 39 Row 32

	92/06/22	LM85303517373x0
	85/06/19	LM85047517442x0
41/32	73/06/27	LM8133917423500
42/32	74/06/23	LM8170017404500

Path 39 Row 33

	92/08/01	LM84366917231x0
	85/08/22	LM85053917442x0
41/33	72/08/07	LM8101517422500
42/33	74/08/16	LM8175417392500

Path 39 Row 34

	92/08/09	LM85308317375x0
	86/08/09	LM85089117370x0
41/34	72/08/07	LM8101517424500
42/34	73/07/16	LM8135817485500

Path 39 Row 35

	92/09/10	LM85311517374x0
	86/09/10	LM85092317361x0
41/35	72/08/07	LM8101517431500
42/35	72/09/13	LM8105217490500

Path 39 Row 36

	92/09/10	LM85311517380x0
	86/09/10	LM85092317363x0
41/36	72/08/07	LM8101517433500
42/36	72/09/13	LM8105217493500

Path 40 Row 27

	92/07/31	LM85307417412x0
	86/07/31	LM85088217404x0
43/27	72/08/27	LM8103517513500

Second WRS-1 not required?

Path 40 Row 28

	92/07/15	LM85305817415x0
	86/07/31	LM85088217410x0
43/28	73/07/17	LM8135917521500

Second WRS-1 not required?

Path 40 Row 29

	92/07/31	LM85307417420x0	
	86/07/31	LM85088217413x0	
43/29	75/07/25	LM8509717281500	OR
	74/07/12	LM8171917443500	fiche missing

Second WRS-1 not required?

Path 40 Row 30

	92/07/31	LM85307417423x0
	86/07/31	LM85088217415x0
43/30	74/07/12	LM8171917450500

Second WRS-1 not required?

Path 40 Row 31

	92/07/07	LM84364417275x0
	86/07/31	LM85088217422x0
43/31	74/07/12	LM8171917452500

Second WRS-1 not required?

Path 40 Row 32

	92/07/23	LM84366017284x0
	86/07/31	LM85088217424x0
43/32	74/07/12	LM8171917455500

Second WRS-1 not required?

Path 40 Row 33

	92/07/31	LM85307417434x0
	86/07/31	LM85088217430x0
43/33	74/07/12	LM8171917461500

Second WRS-1 not required?

Path 40 Row 34

	92/07/23	LM84366017293x0
	86/07/31	LM85088217433x0
43/34	74/07/12	LM8171917464500

Second WRS-1 not required?

Path 40 Row 35

	92/06/05	LM84361217282x0
	86/06/13	LM85083417453x0
42/35	74/06/23	LM8170017420500
43/35	73/06/29	LM8134117551500

Path 40 Row 36

	92/06/21	LM84362817291x0
	85/06/10	LM85046617521x0
42/36	74/06/23	LM8170017422500
43/36	73/06/29	LM8134117554500

Path 41 Row 26

	92/07/22	LM85306517471x0	Composite with GLIS for composite
	86/08/07	LM85088917461x0	
44/26	72/08/10	LM8101817565500	

Second WRS-1 not required?

Path 41 Row 27

	92/07/22	LM85306517473x0	Composite with
	92/06/20	LM85303317480x0	
	86/08/07	LM85088917461x0	
44/27	72/08/28	LM8103617571500	

Second WRS-1 not required?

Path 41 Row 28

	92/07/22	LM85306517480x0	Composite 2 of 3
	92/07/14	LM84365117330x0	
	92/06/20	LM85303317482x0	
	86/07/19	LM85050517550x0	
44/28	74/07/13	LM8172017495500	

Second WRS-1 not required?

Path 41 Row 29

	92/07/14	LM84365117332x0
	85/07/03	LM85048917553x0
44/29	74/07/13	LM8172017502500

Second WRS-1 not required?

Path 41 Row 30

	92/07/14	LM84365117335x0
	85/07/03	LM85048917555x0
44/30	74/07/13	LM8172017504500

Second WRS-1 not required?

Path 41 Row 31

	92/07/14	LM84365117341x0
	85/07/03	LM85048917562x0
44/31	74/07/13	LM8172017511500

Second WRS-1 not required?

Path 41 Row 32

	92/07/22	LM85306517493x0
	85/07/03	LM85048917564x0
44/32	74/07/13	LM8172017513500

Second WRS-1 not required?

Path 41 Row 33

	92/07/22	LM85306517500x0
	85/07/03	LM85048917570x0
44/33	73/06/30	LM8134218001500

Second WRS-1 not required?

Path 41 Row 34

	92/07/22	LM85306517502x0
	85/07/03	LM85048917573x0
44/34	73/06/30	LM8134218003500

Second WRS-1 not required?

Path 41 Row 35

	92/07/22	LM85306517505x0
	85/07/03	LM85048917575x0
44/35	73/06/30	LM8134218010500

Second WRS-1 no required?

Path 41 Row 36

	92/07/06	LM85304917512x0
	85/07/03	LM85048917582x0
44/36	74/06/25	LM8170217535500

Second WRS-1 not required?

Path 41 Row 37

	92/07/06	LM85304917515x0
	85/07/03	LM85048917584x0
44/37	74/06/25	LM8170217541500

Second WRS-1 not required?

Path 42 Row 26

	92/08/14	LM85308817530x0
	85/07/26	LM85051218002x0
45/26	74/07/14	LM8172117544500
46/26	75/07/10	LM8508217450500

Path 42 Row 27

	92/06/27	LM85304017540x0	
	85/07/10	LM85049618005x0	
45/27	74/07/14	LM8172117551500	
46/27	75/07/10	LM8508217453500	OR f. missing
	73/08/07	LM8138018084500	fiche missing

Path 42 Row 28

	90/07/08	LM85232017512x0	
	85/07/10	LM85049618011x0	
45/28	74/06/26	LM8170317561500	
46/28	75/07/10	LM8508217455500	OR
	73/08/07	LM8138018090500	OR
	72/08/12	LM8102018085500	all fiche missing

Path 42 Row 29

	92/07/29	LM85307217543x0
	85/06/24	LM85048018014x0
45/29	72/08/11	LM8101918035500
46/29	72/08/12	LM8102018092500

Path 42 Row 30

	92/07/13	LM85305617550x0
	86/07/13	LM85086417545x0
45/30	74/06/26	LM8170317570500
46/30	74/06/27	LM8170418024500

Path 42 Row 31

	92/07/21	LM84365817404x0	
	86/07/13	LM85086417552x0	
45/31	74/06/26	LM8170317572500	
46/31	74/06/27	LM8170418031500	

Path 42 Row 32

	92/07/29	LM85307217554x0	
	86/07/29	LM85088017551x0	
45/32	73/08/06	LM8137918050500	OR f. missing
	74/06/26	LM8170317575500	fiche missing
46/32	72/07/25	LM8100218125500	

Path 42 Row 33

	92/07/29	LM85307217560x0	
	86/07/29	LM85088017553x0	
45/33	75/08/05	LM8219517541500	
46/33	72/07/25	LM8100218131500	

Path 42 Row 34

	92/07/29	LM85307217563x0	
	86/07/29	LM85088017555x0	
45/34	75/08/05	LM8219517541500	
46/34	72/07/25	LM8100218134500	

Path 42 Row 35

	92/06/19	LM84362617411x0
	85/06/16	LM84106617583x0
45/35	74/06/26	LM8170317590500
46/35	74/07/15	LM8172218041500

Path 42 Row 36

	92/08/30	LM85310417565x0
	85/09/12	LM85056018034x0
45/36	74/08/19	LM8175717574500

Second WRS-1 not required?

Path 43 Row 26

	90/07/15	LM85232717564x0
	85/08/18	LM85053518062x0
46/26	75/07/01	LM8508217450500
47/26	73/08/08	LM8138118140500

Path 43 Row 27

	90/07/15	LM85232717571x0	
	86/07/20	LM85087117594x0	
46/27	75/07/10 73/08/07	LM8508217453500 LM8138018084500	OR fiche missing
47/27	73/08/08	LM8138118142500	

Path 43 Row 28

	92/07/28	LM84366517455x0	
	86/07/20	LM85087118000x0	
46/28	72/08/12	LM8102018085500	OR
	73/08/07	LM8138018090500	OR
	75/07/10	LM8508217455500	fiche missing
47/28	73/08/08	LM8138118145500	

Path 43 Row 29

	92/07/28	LM84366517461x0	
	86/07/20	LM85087118002x0	
46/29	72/08/12	LM8102018092500	OR
	73/08/07	LM8138018093500	fiche missing
47/29	73/08/08	LM8138118151500	

Path 43 Row 30

	92/08/05	LM85307918010x0
	86/08/05	LM85088718001x0
46/30	73/08/07	LM8138018095500
47/30	73/08/08	LM8138118154500

Path 43 Row 31

	92/08/13	LM84368117473x0
	86/08/21	LM85090318000x0
46/31	73/08/07	LM8138018102500
47/31	73/08/08	LM8138118160500

Path 43 Row 32

	92/07/28	LM84366517472x0
	86/07/20	LM85087118014x0
46/32	72/07/25	LM8100218125500
47/32	73/07/26	LM8100318170500

Path 43 Row 33

	92/08/05	LM85307918021x0
	86/08/05	LM85088718013x0
46/33	72/07/25	LM8100218131500
47/33	72/07/26	LM8100318173500

Path 43 Row 34

	92/08/05	LM85307918023x0
	85/08/05	LM85051918094x0
46/34	72/07/25	LM8100218134500
47/34	74/06/28	LM8170518100500

Path 43 Row 35

	92/09/06	LM85311118023x0
	85/08/18	LM85053518095x0
46/35	72/09/17	LM8102018115500

Second WRS-1 not required?

Path 43 Row 36

	92/09/06	LM85311118025x0	
	85/08/18	LM85053518101x0	
46/36	72/09/17	LM8105618123500	check fiche

Second WRS-1 not required?

Path 44 Row 26

	92/07/19	LM84365617510x0
	85/07/08	LM85049418125x0
47/26	73/08/08	LM8138118140500
48/26	72/07/27	LM8100418194500

Path 44 Row 27

	91/08/02	LM84330417591x0
	85/08/25	LM85054218125x0
47/27	73/08/08	LM8138118142500
48/27	72/07/27	LM8100418201500

Path 44 Row 28

	92/08/20	LM84368817524x0
	86/08/12	LM85089418052x0
47/28	73/08/08	LM8138118145500
48/28	72/07/27	LM8100418203500

Path 44 Row 29

	92/08/20	LM84368817530x0
	85/08/25	LM85054218133x0
47/29	73/08/08	LM8138118151500
48/29	72/07/27	LM8100418210500

Path 44 Row 30

	92/08/28	LM85310218065x0
	86/08/12	LM85089418061x0
47/30	73/08/08	LM8138118154500
48/30	72/07/27	LM8100418212500

Path 44 Row 31

	92/08/04	LM84367217532x0
	85/08/09	LM85052618143x0
47/31	73/08/08	LM8138118160500
48/31	72/07/27	LM8100418215500

Path 44 Row 32

	92/08/04	LM84367217535x0
	86/08/12	LM85089418070x0
47/32	73/07/26	LM8100318170500
48/32	72/07/27	LM8100418221500

Path 44 Row 33

	92/08/04	LM84367217541x0	
	86/08/12	LM85089418072x0	
47/33	72/07/26	LM8100318173500	
48/33	73/07/22	LM8136418225500	Bad fiche

Path 44 Row 34

	92/08/04	LM84367217544x0
	85/07/08	LM85049418160x0
47/34	74/06/28	LM8170518100500

Second WRS-1 not required?

Path 44 Row 35

	92/09/13	LM85311818083x0
	84/09/07	LM85019018163x0
47/35	72/08/13	LM8102118174500

Second WRS-1 not required?

Path 45 Row 26

	92/08/11	LM84367917575x0
	86/08/19	LM85090118103x0
49/26	73/09/15	LM8141918244500
48/26	72/07/27	LM8100418194500

Path 45 Row 27

	92/08/03	LM85307718121x0
	86/08/19	LM85090118105x0
49/27	73/09/15	LM8141918251500
48/27	72/07/27	LM8100418201500

Path 45 Row 28

	92/08/03	LM85307718123x0
	86/08/19	LM85090118112x0
49/28	72/09/02	LM8104118262500
48/28	72/07/27	LM8100418203500

Path 45 Row 29

	92/08/03	LM85307718130x0
	86/08/19	LM85090118114x0
49/29	72/09/02	LM8104118265500
48/29	72/07/27	LM8100418210500

Path 45 Row 30

	92/08/03	LM85307718132x0
	86/08/19	LM85090118120x0
49/30	72/09/02	LM8104118271500
48/30	72/07/27	LM8100418212500

Path 45 Row 31

	92/08/03	LM8530771834x0	
	86/08/19	LM85090118123x0	
49/31	73/08/28	LM8140118271500	Fiche missing
48/31	72/07/27	LM8100418215500	

Path 45 Row 32

	92/09/04	LM85310918134x0	
	86/08/19	LM85090118125x0	
49/32	73/08/28	LM8140118273500	Fiche missing
48/32	72/07/27	LM8100418221500	

Path 45 Row 33

	92/09/04	LM85310918140x0	
	86/08/19	LM85090118132x0	
49/33	73/08/28	LM8140118280500	Fiche missing
48/33	73/07/22	LM8136418225500	EROS Check Film

Path 46 Row 26

	92/08/18	LM84368618041x0	
	85/08/23	LM85054018244x0	
49/26	73/09/16	LM8141918244500	
50/26	73/09/16	LM8142018303500	

Path 46 Row 27

	92/08/10	LM85308418181x0
	85/08/23	LM85054018251x0
49/27	73/09/15	LM8141918251500
50/27	72/07/27	LM8100418201500

Path 46 Row 28

	92/08/10	LM85308418184x0
	85/08/23	LM85054018253x0
49/28	72/09/02	LM8104118262500
50/28	72/07/29	LM8100618315500

Path 46 Row 29

	92/08/26	LM85310018185x0
	85/09/24	LM85057218253x0
49/29	72/09/02	LM8104118265500
50/29	72/07/29	LM8100618322500

Path 46 Row 30

	92/08/10	LM85308418193x0
	86/08/10	LM85089218183x0
49/30	72/09/02	LM8104118271500
50/30	72/07/29	LM8100618324500

Path 46 Row 31

	92/08/10	LM85308418195x0	
	84/07/03	LM85012418254x0	
49/31	73/07/23	LM8136518274500	Black fiche
50/31	73/07/24	LM8136618332500	

Path 46 Row 32

	92/07/09	LM85305218204x0	
	84/07/03	LM85015618270x0	
49/32	73/08/28	LM8140118273500	Fiche missing

Second WRS-1 not required?

Path 47 Row 26

	92/07/16	LM85305918242x0
	86/08/01	LM85088318233x0
50/26	73/09/16	LM8142018303500
51/26	74/09/12	LM8178118265500

Path 47 Row 27

	92/07/16	LM85305918244x0
	86/08/01	LM85088318235x0
50/27	75/07/23	LM8218218201500
51/27	74/09/12	LM8178118272500

Path 47 Row 28

	92/07/16	LM85305918251x0
	86/05/29	LM85081918262x0
50/28	75/07/23	LM8218218204500
51/28	74/09/12	LM8178118274500

Path 47 Row 29

	92/07/16	LM85305918253x0
	86/05/29	LM85081918265x0
50/29	72/07/29	LM8100618322500

Second WRS-1 not required?

Path 47 Row 30

	92/07/16	LM85305918260x0
	86/06/30	LM85305918260x0
50/30	72/07/29	LM8100618324500

Second WRS-1 not required?

Path 48 Row 26

	92/09/09	LM85311418294x0
	86/08/08	LM85089018293x0
51/26	74/09/12	LM8178118265500
52/26	74/09/13	LM8178218324500

Path 48 Row 27

	92/09/09	LM85311418301x0
	84/07/17	LM85047418380x0
51/27	74/09/12	LM8178118272500

Second WRS-1 not required?

NALC MSS Triplicates - Eastern and Southern US

Path 6 Row 38 To be selected

Path 10 Row 29

	91/07/11	LM85268814370x0	Composite with
	91/06/25	LM85267214370x0	
	86/08/14	LM85089614353x0	
11/29	75/07/02	LM8216114374500	

Second WRS-1 not required? .

Path 11 Row 27

	91/06/16	LM85266314421x0
	85/07/01	LM85048714492x0
11/27	74/08/21	LM8175914384500
12/27	76/06/09	LM8250414361500

Path 11 Row 28

	91/06/16	LM85266314423x0
	85/07/01	LM85048714494x0
11/28	76/08/19	LM8257514285500
12/28	73/07/22	LM8136414541500

Path 11 Row 29

	91/07/02	LM85267914431x0
	85/07/01	LM85048714500x0
11/29	75/07/02	LM8216114374500
12/29	74/07/17	LM8172414463500

Path 11 Row 31

	92/08/21	LM85309514432x0
	86/08/05	LM85088714425x0
12/31	74/07/17	LM8172414472500

Path 12 Row 27

	91/06/07	LM85265414481x0
	86/07/27	LM85087814475x0
12/27	76/06/09	LM8250414361500
13/27	73/07/23	LM8136514593500

Path 12 Row 28

	91/06/07	LM85265414484x0
	85/06/22	LM85047814555x0
12/28	73/07/22	LM8136414541500
13/28	73/07/23	LM8136514595500

Path 12 Row 29

	91/06/07	LM85265414490x0
	85/06/22	LM85047814562x0
12/29	74/07/17	LM8172414463500
13/29	73/07/23	LM8136515002500

Path 12 Row 30

	92/08/12	LM85308614492x0
	86/09/13	LM85092614471x0
13/30	73/07/23	LM8136515004500

Second WRS-1 not required?

Path 12 Row 31

	91/06/07	LM85265414495x0
	85/08/09	LM85052614564x0
12/31	74/07/17	LM8172414472500
13/31	73/07/23	LM8136515011500

Path 13 Row 28

	91/06/14	LM85266114545x0
	84/06/10	LM85010115001x0
14/28	75/06/26	LM8506814431500

Second WRS-1 not required?

Path 13 Row 29

	92/06/16	LM85302914554x0
	84/06/10	LM85010115004x0
14/29	74/06/13	LM8169014591500

Second WRS-1 not required?

Path 13 Row 30

	92/09/20	LM85312514545x0
	85/09/17	LM85056515020x0
14/30	73/08/29	LM8140215060500

Second WRS-1 not required?

Path 13 Row 31

	91/07/16	LM85269314563x0
	84/06/10	LM85010115013x0
14/31	74/06/13	LM8169015000500

Second WRS-1 not required?

Path 13 Row 32

	91/07/16	LM85269314570x0
	84/06/10	LM85010115015x0
14/32	74/06/13	LM8169015002500

Second WRS-1 not required?

Path 14 Row 29

	91/08/08	LM85271615021x0
	86/08/26	LM85090814595x0
15/29	76/06/03	LM8541114274500

Second WRS-1 not required?

Path 14 Row 35

	91/07/23	LM85274815045x0
	86/07/09	LM85086015040x0
15/35	75/06/18	LM8214715031500

Second WRS-1 not required?

Path 14 Row 36

	90/09/06	LM85238015011x0
	86/09/27	LM85094015013x0
15/36	73/08/30	LM8140315141500

Path 15 Row 29

	92/07/16	LM85305915075x0
	85/07/13	LM85049915144x0
16/29	75/06/10	LM8505214560500
17/29	72/08/19	LM8102715231500

Path 15 Row 35

	91/10/18	LM85278715112x0
	85/09/15	LM85056315163x0
15/35	73/08/30	LM8140315134500
16/35	72/10/11	LM8108015201500

Path 15 Row 36

	91/10/18	LM85278715114x0
	85/09/15	LM85056315165x0
15/36	73/08/30	LM8140315141500
16/36	72/10/11	LM8108015203500

Path 15 Row 37

	91/10/18	LM85278715121x0
	85/08/14	LM85053115171x0
16/37	72/10/11	LM8108015210500

Second WRS-1 not required?

Path 15 Row 41

	92/05/13	LM85299515132x0
	86/04/27	LM8507871544x0
16/41	73/04/09	LM8126015233500

Second WRS-1 not required?

Path 15 Row 42

	91/03/08 91/02/20	LM85256315111x0 LM85254715105x0	Composite with
	86/04/27	LM85078715151x0	
16/42	73/03/22	LM8124215240500	

Second WRS-1 not required?

Path 15 Row 43

	92/05/13	LM85299515140x0
	86/04/27	LM85078715153x0
16/43	75/02/13	LM8202215122500

Second WRS-1 not required?

Path 16 Row 35

	91/10/09	LM85277815172x0
	85/09/06	LM85055415224x0
17/35	75/08/22	LM8512514595500

Second WRS-1 not required?

Path 16 Row 36

	90/10/06	LM85241015132x0
	85/09/06	LM85055415231x0
17/36	72/10/12	LM8108115262500

Second WRS-1 not required?

Path 16 Row 37

	92/10/06	LM85241015134x0
	86/09/25	LM85093815142x0
17/37	72/10/12	LM8108115264500

Second WRS-1 not required?

Path 16 Row 38

	91/08/06	LM85271415180x0	
	86/08/24	LM85090615155x0	
17/38	72/08/19 74/08/27	LM8102715265500 LM8176515173500	OR (EROS Check)

Second WRS-1 not required?

Path 16 Row 39

	92/05/04	LM85298615184x0
	85/05/17	LM85044215250x0
17/39	74/05/11	LM8165715213500

Second WRS-1 not required?

Path 16 Row 40

	92/03/17	LM85293815193x0
	86/04/02	LM85076215210x0
17/40	73/04/10	LM8126115285500

Second WRS-1 not required?

Path 16 Row 41

	92/03/17	LM85293815200x0
	86/04/18	LM85077815211x0
16/41	73/04/09	LM8126015233500
17/41	73/04/28	LM8127915291500

Path 16 Row 42

	92/05/04	LM85298615195x0
	86/04/18	LM85077815213x0
16/42	73/03/22	LM8122415240500
17/42	75/04/09	LM8207715173500

Path 17 Row 30

	92/06/28	LM85304115204x0
	85/07/27	LM85051315272x0
18/30	75/06/30	LM8507215064500
19/30	74/07/06	LM8171315273500

Path 17 Row 33

	92/10/02	LM85313715203x0
	85/09/29	LM85057715275x0
18/33	76/09/13	LM8260015103500
19/33	73/09/03	LM8140715355500

Path 17 Row 35

	92/10/02	LM85313715211x0	
	84/10/12	LM85022515294x0	
18/35	72/09/07	LM8104615313500	
19/35	73/10/27	LM8146115352500	OR (if too late)
	73/07/29	LM8137115371500	

Path 17 Row 36

	91/09/30	LM85276915235x0
	86/10/18	LM85096115192x0
18/36	72/09/07	LM8104615315500
19/36	73/09/03	LM8140715370500

Path 17 Row 37

	90/09/27	LM85240115200x0
	86/10/18	LM85096115195x0
18/37	74/10/21	LM8182015212500
19/37	74/10/04	LM8183915262500

Path 17 Row 38

	90/10/29	LM85243315201x0
	86/10/18	LM85096115201x0
18/38	72/10/31	LM8110015331500
19/38	74/10/04	LM8180315273500

Path 17 Row 39

	91/10/16	LM85278515252x0
	84/10/12	LM85022515311x0
18/39	72/10/13	LM8108215332500
19/39	72/10/14	LM8108315390500

Path 17 Row 40

	91/10/16	LM85278515254x0
	84/10/12	LM85022515314x0
18/40	74/10/21	LM8182015223500

Second WRS-1 not required?

Path 17 Row 41

	91/10/16	LM85278515260x0
	86/10/18	LM85096115212x0
18/40	73/11/13	LM8147815315500

Second WRS-1 not required?

Path 18 Row 31

	92/06/03	LM85301615274x0
	86/06/03	LM85082415281x0
19/31	74/07/06	LM8171315275500
20/31	74/07/07	LM8171415334500

Path 18 Row 32

	90/08/17	LM85236015243x0
	85/07/18	LM85050415343x0
19/32	73/09/03	LM8140715352500
20/32	73/09/04	LM8140815410500

Path 18 Row 33

	91/09/21	LM85276015285x0	
	84/09/17	LM85020015350x0	
19/33	73/09/03	LM8140715355500	
20/33	73/09/04	LM8140815413500	

Path 18 Row 34

	91/09/21	LM85276015292x0	
	84/09/17	LM85020015352x0	
19/34	73/09/03	LM8140715361500	
20/34	74/10/05	LM8180415313500	

Path 18 Row 35

	90/10/10	LM85242415251x0	
	84/10/03	LM85021615355x0	
19/35	73/10/27	LM8146115352500	OR (if too late)
	73/07/29	LM8137115371500	
20/35	72/10/15	LM8108415431500	

Path 18 Row 36

	90/10/20	LM85242415254x0	
	84/10/03	LM85021615361x0	
19/36	73/09/03	LM8140715370500	
20/36	72/10/15	LM8108415433500	

Path 18 Row 37

	90/10/20	LM85242415260x0
	85/10/06	LM85058415353x0
19/37	74/10/04	LM8180315271500
20/37	72/10/15	LM8104815434500

Path 18 Row 38

	90/10/20	LM85242415263x0
	85/10/06	LM85058415360x0
19/38	74/10/04	LM8180315273500
20/38	74/10/23	LM8182215331500

Path 18 Row 39

	90/09/18	LM85239215271x0
	85/10/06	LM85058415362x0
19/39	72/10/14	LM8108315390500
20/39	74/10/23	LM8182215333500

Path 19 Row 31

	91/06/08	LM85265515331x0	
	85/06/23	LM85047915402x0	
20/31	74/07/07	LM8171415334500	
21/31	73/06/07	LM8131915474500	OR (EROS Check)
	75/07/30	LM8218915352500	

Path 19 Row 32

	92/08/29	LM85310315330x0	
	86/08/29	LM85091115315x0	Composite with
	86/08/13	LM85089515322x0	
20/32	73/09/04	LM8140815410500	
21/32	73/07/13	LM8135515474500	

Path 19 Row 33

	92/08/29	LM85310315333x0
	84/09/08	LM85019115411x0
20/33	73/09/04	LM8140815413500
21/33	74/10/06	LM8180515365500

Path 19 Row 34

	90/09/25	LM85239915311x0
	84/09/08	LM85019115413x0
20/34	74/10/05	LM8180415313500
21/34	74/10/06	LM8180515372500

Path 19 Row 35

	92/09/30	LM85313515334x0
	86/09/14	LM85092715323x0
20/35	72/10/15	LM8108415431500
21/35	74/10/06	LM8180515374500

Path 19 Row 36

	91/09/28	LM85276715361x0
	84/09/08	LM85019115422x0
20/36	72/10/15	LM8108415433500
21/36	74/10/06	LM8180515381500

Path 19 Row 37

	91/09/28	LM85276715364x0
	83/10/16	LM84045715421x0
20/37	72/10/15	LM8108415440500
21/37	74/10/06	LM8180515383500

Path 19 Row 38

	91/10/14	LM85278315371x0
	86/10/16	LM85095915324x0
20/38	74/10/23	LM8182215331500
21/38	72/10/16	LM8108515501500

Path 19 Row 39

	91/10/14	LM85278315374x0
	86/10/16	LM85095915330x0
20/39	74/10/23	LM8182215333500
21/39	72/10/16	LM8106715501500

Path 20 Row 29

	92/08/20	LM85309415381x0
	86/08/20	LM85091215371x0
21/29	75/08/08	LM8511115211500
22/29	75/07/31	LM8219015401500

Path 20 Row 30

	92/09/05	LM85311015382x0
	86/08/20	LM85090215373x0
21/30	75/08/08	LM8511115214500
22/30	75/07/31	LM8219015404500

Path 20 Row 31

	90/08/31	LM85237415362x0
	85/08/09	LM84112015402x0
21/31	75/07/30	LM8218915352500
22/31	75/07/31	LM8219015410500

Path 20 Row 32

	91/08/02	LM85271015402x0
	86/08/04	LM85088615385x0
21/32	73/07/13	LM8135515474500
22/32	74/07/09	LM8171615453500

Path 20 Row 33

	91/08/02	LM85271015404x0
	86/08/04	LM85088615392x0
21/33	75/08/08	LM8511115225500
22/33	76/07/25	LM8255015345500

Path 20 Row 34

	92/10/07	LM85314215391x0
	86/10/07	LM85095015373x0
21/34	74/10/06	LM8180515372500
22/34	76/08/30	LM8258615341500

Path 20 Row 35

	90/09/16	LM85239015375x0
	86/10/07	LM85095015375x0
21/35	74/10/06	LM8180515374500
22/35	75/10/20	LM8518415251500

Path 20 Row 36

	90/09/16	LM85239015382x0
	86/07/19	LM85087015410x0
21/36	74/10/06	LM8180515381500
22/36	75/10/02	LM8516615264500

Path 20 Row 37

	90/09/16	LM85229415390x0
	86/09/21	LM85093415391x0
21/37	74/10/06	LM8180515383500
22/37	74/10/07	LM8180615442500

Path 20 Row 38

	90/09/16	LM85231015393x0
	84/10/01	LM85021415492x0
21/38	74/09/18	LM8178715100500
22/38	74/10/07	LM8180615444500

Path 20 Row 39

	90/09/16	LM85239015393x0
	84/10/01	LM85021415495x0
21/39	72/10/16	LM8108515503500
22/39	74/10/07	LM8180615451500

Path 21 Row 28

	91/07/08	LM85268515444x0	
	86/06/24 86/06/08	LM85084515445x0 LM85082915453x0	OR
22/28	75/07/31	LM8219015395500	
23/28	74/07/10 75/06/26	LM8171715493500 LM8215515460500	OR (EROS Check)

Path 21 Row 29

	91/08/09	LM85271715452x0
	85/08/08	LM85052515513x0
22/29	75/07/31	LM8219015401500
23/29	75/08/01	LM8219115460500

Path 21 Row 30

	91/08/25	LM85273315455x0
	85/07/23	LM85050915521x0
22/30	75/07/31	LM8219015404500
23/30	75/08/01	LM8219115462500

Path 21 Row 31

	91/08/25	LM85273315462x0
	85/07/23	LM85050915523x0
22/31	75/08/27	LM8513015264500
23/31	74/08/15	LM8175315493500

Path 21 Row 32

	91/06/06	LM85265315455x0
	84/06/02	LM85009315511x0
22/32	73/06/08	LM8132015534500
23/32	73/06/09	LM8132115593500

Path 21 Row 33

	92/09/28	LM85313315452x0	
	85/09/01	LM84114315465x0	
22/33	75/10/02	LM8516615252500	
23/33	72/09/30	LM8106915591500	

Path 21 Row 34

	92/09/28	LM85313315454x0	
	86/09/28	LM85094115440x0	
22/34	76/08/30	LM8258615341500	
23/34	72/09/30	LM8106915594500	

Path 21 Row 35

	91/09/26	LM85276515481x0	
	86/09/28	LM85094115442x0	
22/35	75/10/20	LM8518415251500	
23/35	72/09/12	LM8105116000500	Faded fiche (EROS Check)

Path 21 Row 36

	91/09/26	LM85276515483x0	
	86/09/28	LM85094115445x0	
22/36	75/10/02	LM8226215421500	
23/36	73/08/20	LM8139316001500	Black fiche (EROS check)

Path 21 Row 37

	91/09/26	LM85276515490x0	
	86/09/29	LM85094115451x0	
22/37	74/10/07	LM8180615442500	
23/37	74/09/20	LM8178915503500	

Path 21 Row 38

	91/09/26	LM85276515492x0	
	86/09/28	LM85094115453x0	
22/38	74/10/07	LM8180615444500	
23/38	72/09/12	LM8105116012500	Faded Fiche (EROS Check)

Path 21 Row 39

	92/10/14	LM85314915472x0	
	84/09/06	LM85018915560x0	
22/39	74/10/07	LM8180615451500	
23/39	74/10/08	LM8180715505500	

Path 21 Row 40

	92/10/14	LM85314915474x0	
	85/09/09	LM85055715554x0	
22/40	75/10/11	LM8226215435500	
23/40	74/10/08	LM8180715512500	

Path 22 Row 27

	91/07/15	LM85269215503x0	
	86/08/18	LM85090015485x0	
23/27	75/06/26	LM8215515454500	
24/27	73/07/16	LM8135816024500	

Path 22 Row 28

	91/07/15	LM85269215510x0	
	85/06/28	LM85048415574x0	
23/28	74/07/10	LM8171715493500	OR (EROS Check)
	75/06/26	LM8215515460500	
24/28	74/07/11	LM8171815551500	

Path 22 Row 29

	91/07/15	LM85269215512x0
	85/06/28	LM85048415580x0
23/29	73/06/09	LM8132115581500
24/29	73/06/10	LM8132216042500

Path 22 Row 30

	91/07/15	LM85269215514x0
	85/06/28	LM85048415583x0
23/30	73/06/09	LM8132115584500
24/30	73/06/10	LM8132216042500

Path 22 Row 31

	91/07/15	LM85269215521x0
	85/07/22	LM84110215530x0
23/31	73/06/09	LM8132115590500
24/31	73/06/10	LM8132216045500

Path 22 Row 32

	92/10/05	LM85314015505x0
	85/10/02	LM85058015582x0
23/32	75/10/12	LM8226315461500
24/32	74/09/21	LM8179015541500

Path 22 Row 33

	92/10/05	LM85314015511x0
	85/10/02	LM85058015584x0
23/33	74/10/08	LM8180715482500
24/33	74/10/09	LM8180815541500

Path 22 Row 34

	92/10/05	LM85314015514x0
	85/09/16	LM85056415592x0
23/34	72/09/30	LM8106915594500
24/34	74/10/09	LM8180815543500

Path 22 Row 35

	92/10/05	LM85314015520x0	
	85/09/16	LM85056415594x0	
23/35	72/09/12	LM8105116000500	
24/35	72/10/01	LM8107016055500	Prime
	75/09/07	LM8222815533500	Alternate

Path 22 Row 36

	91/07/31	LM85270815542x0	
	86/07/17	LM85086815533x0	
23/36	73/08/20	LM8139316001500	Black fiche (EROS Check)
24/36	74/07/29	LM8173615575500	

Path 22 Row 37

	92/10/05	LM85314015525x0
	86/10/21	LM85096415504x0
23/37	72/09/12	LM8105116005500
24/37	75/10/13	LM8226415540500

Path 22 Row 38

	92/10/05	LM85314015531x0
	85/08/31	LM85054816011x0
23/38	74/10/08	LM8180715503500
24/38	75/10/13	LM8226415543500

Path 22 Row 39

	92/10/05	LM85314015534x0
	85/08/31	LM85054816013x0
23/39	74/10/08	LM8180715505500
24/39	72/10/01	LM8107016073500

Path 22 Row 40

	92/10/05	LM85314015540x0
	85/08/31	LM85054816015x0
23/40	74/10/08	LM8180715512500
24/40	74/10/09	LM8180815570500

Path 23 Row 27

	91/06/04	LM85265115561x0
	85/06/03	LM85045916033x0
24/27	73/07/16	LM8135816024500
25/27	74/06/24	LM8170116010500

Path 23 Row 28

	91/06/04	LM85265115564x0
	86/08/09	LM85089115554x0
24/28	74/07/11	LM8171815551500
25/28	75/07/16	LM8217515572500

Path 23 Row 29

	91/06/04	LM85265115570x0
	85/06/03	LM85045916042x0
24/29	74/07/11	LM8171815554500
25/29	73/07/17	LM8135916091500

Path 23 Row 30

	91/06/04	LM85265115572x0
	85/06/03	LM85045916044x0
24/30	73/06/10	LM8132216042500
25/30	73/06/11	LM8132316100500

Path 23 Row 31

	92/09/10	LM85311515571x0
	85/09/07	LM85055516042x0
24/31	75/09/07	LM8222815515500
25/31	72/10/02	LM8107116095500

Path 23 Row 32

	90/09/05	LM85237915551x0
	84/09/20	LM85020316053x0
24/32	74/09/21	LM8179015541500
25/32	72/10/02	LM8107116102500

Path 23 Row 33

	90/09/05	LM85237915554x0
	84/09/20	LM85020316060x0
24/33	74/10/09	LM8180815541500
25/33	72/10/02	LM8107116104500

Path 23 Row 34

	90/09/05	LM85237915560x0
	84/09/20	LM85020316062x0
24/34	74/10/09	LM8180815543500
25/34	72/10/02	LM8107116111500

Path 23 Row 35

	90/09/05	LM85237915563x0	
	84/09/20	LM85020316064x0	
24/35	75/09/07	LM8222815533500	OR (EROS Check)
	73/08/21	LM8139416053500	
25/35	72/10/02	LM8107116113500	

Path 23 Row 36

	92/10/12	LM85314715583x0
	84/09/20	LM85020316071x0
24/36	74/07/29	LM8173615575500
25/36	72/10/02	LM8107116120500

Path 23 Row 37

	92/10/12	LM85314715585x0	
	84/09/20	LM85020316073x0	
24/37	75/10/13	LM8226415540500	
25/37	72/10/02	LM8107116122500	

Path 23 Row 38

	91/10/10	LM85277916015x0	
	86/08/25	LM85090715590x0	
24/38	75/10/13	LM8226415543500	
25/38	72/10/02	LM8107116125500	

Path 23 Row 39

	92/10/12	LM85314715594x0	
	86/08/25	LM85090715593x0	
24/39	72/10/01	LM8107016073500	OR (EROS Check)
	75/09/25	LM8224615550500	
25/39	74/10/10	LM8180916022500	

Path 23 Row 40

	92/10/12	LM85314716001x0	
	86/08/25	LM85090715595x0	OR (EROS Check)
	84/10/06	LM85021916084x0	
24/40	74/10/09	LM8180815570500	
25/40	74/10/10	LM8180916025500	

Path 24 Row 27

	92/06/29	LM85304216025x0
	85/08/13	LM85053016092x0
26/27	74/06/25	LM8170216065500
27/27	76/06/06	LM8250116022500

Path 24 Row 28

	90/06/24	LM85230616001x0
	85/07/12	LM85049816100x0
26/28	75/07/17	LM8217616030500
27/28	74/06/26	LM8170316125500

Path 24 Row 29

	91/08/14	LM85272216035x0
	86/08/16	LM85089816020x0
26/29	73/08/05	LM8137816144500
27/29	73/09/11	LM8141516195500

Path 24 Row 30

	90/09/04	LM84297216090x0
	86/09/01	LM85091416015x0
26/30	72/08/28	LM8103616152500
27/30	72/08/29	LM8103716210500

Path 24 Row 31

	92/10/03	LM85313816025x0
	86/09/01	LM85091416021x0
25/31	GLIS for scene	
26/31	74/09/05	LM8177416055500

Path 24 Row 32

	92/10/03	LM85313816032x0
	85/10/16	LM85059416103x0
25/32	72/10/02	LM8107116102500
26/32	73/10/16	LM8145016142500

Path 24 Row 33

	92/10/03	LM85313816034x0
	85/10/16	LM85059416110x0
25/33	72/10/02	LM8107116104500
26/33	73/10/16	LM8145016145500

Path 24 Row 34

	91/10/17	LM85278616063x0
	85/10/16	LM85059416112x0
25/34	72/10/02	LM8107116111500
26/34	72/08/28	LM8103616165500

Path 24 Row 35

	92/10/03	LM85313816043x0
	85/10/16	LM85059416114x0
25/35	72/10/02	LM8107116113500
26/35	74/07/31	LM8173816085500

Path 24 Row 36

	92/10/19	LM85315416044x0
	85/10/16	LM85059416121x0
25/36	72/10/02	LM8107116120500
26/36	75/09/27	LM8224816051500

Path 24 Row 37

	92/10/19	LM85315416050x0
	86/10/19	LM85096216030x0
25/37	72/10/02	LM8107116122500
26/37	75/09/27	LM8224816054500

Path 24 Row 38

	92/10/19	LM85315416053x0
	86/09/17	LM85093016043x0
25/38	72/10/02	LM8107116125500
26/38	72/10/03	LM8107216183500

Path 24 Row 39

	92/10/19	LM85315416055x0
	86/10/19	LM85096216035x0
25/39	74/10/10	LM8180916022500
26/39	72/10/03	LM8107216190500

Path 25 Row 26

	92/06/20	LM85303316084x0
	86/07/06	LM85085716083x0
26/26	76/06/05	LM8250015561500
27/26	76/07/03	LM8544115325500

Path 25 Row 27

	91/08/05	LM85271316092x0
	86/07/22	LM85087316082x0
26/27	74/06/25	LM8170216065500
27/27	76/06/05	LM8250116022500

Path 25 Row 28

	91/08/05	LM85271316094x0
	86/07/22	LM85087316084x0
26/28	75/07/17	LM8217616030500
27/28	74/06/26	LM8170316125500

Path 25 Row 29

	92/09/08	LM85311316085x0
	86/09/08	LM85092116072x0
26/29	73/08/05	LM8137816144500
27/29	73/09/11	LM8141516195500

Path 25 Row 30

	92/09/08	LM85311316091x0
	86/09/08	LM85092116074x0
26/30	72/08/28	LM8103616152500
27/30	73/09/11	LM8141516202500

Path 25 Row 31

	92/09/08	LM85311316093x0
	86/09/08	LM85092116081x0
26/31	74/09/05	LM8177416055500
27/31	72/08/29	LM8103716213500

Path 25 Row 32

	92/09/24	LM85312916094x0
	86/09/08	LM85092116083x0
26/32	73/08/05	LM8137816160500
27/32	74/08/19	LM8175716124500

Path 25 Row 33

	92/09/24	LM85312916100x0
	84/09/18	LM85020116182x0
26/33	73/10/16	LM8145016145500
27/33	72/10/04	LM8107316221500

Path 25 Row 34

	92/09/24	LM85312916100x0
	84/09/18	LM85020116182x0
26/34	72/08/28	LM8103616165500
27/34	72/10/04	LM8107316224500

Path 25 Row 35

	90/08/26	LM84296316172x0
	85/08/28	LM84113916122x0
26/35	74/07/31	LM8173816085500
27/35	72/08/11	LM8101916225500

Path 25 Row 36

	91/10/08	LM85277716132x0
	84/07/08	LM84072316143x0
26/36	75/09/27	LM8224816051500
27/36	72/10/04	LM8107316233500

Path 25 Row 37

	91/10/08	LM85277716135x0
	84/07/08	LM84072316145x0
26/37	75/09/27	LM8224816051500
27/37	72/10/04	LM8107316235500

Path 25 Row 38

	92/07/06	LM85304916132x0
	84/09/18	LM85020116202x0
26/38	74/07/13	LM8172016105500
27/38	73/07/19	LM8136116243500

Path 25 Row 39

	92/07/06	LM85304916134x0
	85/06/01	LM85045716204x0
26/39	74/07/13	LM8172016111500
27/39	74/06/26	LM8170316173500

Path 25 Row 40

	92/07/06	LM85304916140x0
	85/06/01	LM85045716210x0
26/40	76/06/23	LM8251816014500
27/40	74/06/26	LM8170316175500

NALC MSS Triplicates - Midwest and Great Plains

Path 26 Row 27

	91/08/12	LM85272016153x0
	86/07/29	LM85088016141x0
28/27	72/08/12	LM8102016252500

Second WRS-1 not required?

Path 26 Row 28

	91/08/28	LM85273616160x0
	85/09/12	LM85056016214x0
28/28	72/08/12	LM8102016255500

Second WRS-1 not required?

Path 26 Row 29

	90/08/25	LM85236816124x0
	85/09/12	LM85056016220x0
27/29	73/09/11	LM8141516195500
28/29	74/09/25	LM8179416154500

Path 26 Row 30

	92/08/30	LM85310416153x0
	85/07/10	LM85049616231x0
27/30	73/09/11	LM8141516202500
28/30	74/09/25	LM8179416160500

Path 26 Row 31

	92/08/30	LM85310416155x0
	84/08/08	LM85016016231x0
27/31	72/08/29	LM8103716213500
28/31	74/09/25	LM8179416163500

Path 26 Row 32

	92/10/01	LM85313616154x0
	86/10/17	LM85096016133x0
27/32	74/08/19	LM8175716124500
28/32	74/09/25	LM8179416165500

Path 26 Row 33

	92/10/01	LM85313616160x0
	86/10/17	LM85096016135x0
27/33	72/10/14	LM8107316221500
28/33	74/09/25	LM8179416165500

Path 26 Row 34

	92/10/01	LM85313616163x0
	86/10/17	LM85096016142x0
27/34	72/10/04	LM8107316224500
28/34	72/09/17	LM8105616282500

Path 26 Row 35

.	90/08/25	LM85236816150x0	
	84/08/24	LM85017616251x0	
27/35	72/08/11	LM8101916225500	
28/35	73/08/25	LM8139816282500	Black fiche (EROS Check)

Path 26 Row 36

	90/06/06	LM85228816154x0	
	85/06/08	LM85046416254x0	
27/36	75/06/12	LM8214116122500	
28/36	74/08/20	LM8175816200500	

Path 26 Row 37

	91/06/25	LM85267216190x0	
	85/06/08	LM85046416260x0	
27/37	75/06/12	LM8214116124500	
28/37	74/06/27	LM8170416222500	

Path 26 Row 38

	91/06/25	LM85267216192x0	
	84/07/15	LM84073016213x0	
27/38	73/07/19	LM8136116243500	
28/38	74/06/27	LM8170416225500	

Path 26 Row 39

	90/07/08	LM85232016165x0
	84/07/15	LM84073016215x0
27/39	74/06/26	LM8170316173500
28/39	74/06/27	LM8170416231500

Path 26 Row 40

	92/10/01	LM85313616185x0
	86/10/17	LM85096016164x0
27/40	76/09/22	LM9260916045500
28/40	75/10/17	LM8226816181500

Path 26 Row 41

	92/10/01	LM85313616192x0
	86/10/17	LM85096016170x0
28/41	73/10/18	LM8145216293500

Second WRS-1 not required?

Path 27 Row 27

	91/06/16	LM85266316210x0	
	84/06/28	LM85011916264x0	
29/27	73/07/03	LM8134516313500	EROS Check Black fiche

Second WRS-1 not required?

Path 27 Row 28

	91/06/16	LM85266316212x0	
	86/06/02	LM85082316224x0	
29/28	73/07/03	LM8134516320500	OR (EROS Check)
	74/06/28	LM8170516242500	

Second WRS-1 not required?

Path 27 Row 29

	92/09/22	LM85312716205x0
	84/09/16	LM85019916290x0
29/29	74/09/26	LM8179516212500

Second WRS-1 not required?

Path 27 Row 30

	92/09/22	LM85312716212x0
	84/10/02	LM85021516293x0
29/30	74/09/26	LM8179516214500

Second WRS-1 not required?

Path 27 Row 31

	92/09/22	LM85312716214x0
	84/10/02	LM85021516295x0
29/31	74/09/26	LM8179516221500

Second WRS-1 not required?

Path 27 Row 32

	92/09/22	LM85312716221x0
	85/08/10	LM84112116235x0
29/32	74/09/26	LM8179516223500

Second WRS-1 not required?

Path 27 Row 33

	92/09/22	LM85312716223x0
	84/08/15	LM85016716302x0
29/33	73/08/26	LM8139916332500

Second WRS-1 not required?

Path 27 Row 34

	92/09/22	LM85312716225x0
	85/10/05	LM85058316300x0
29/34	74/09/08	LM8177716241500

Second WRS-01 not required?

Path 27 Row 35 To be selected

Path 27 Row 36 To be selected

Path 27 Row 37 To be selected

Path 27 Row 38 To be selected

Path 27 Row 39 To be selected

Path 27 Row 40 To be selected

Path 27 Row 41 To be selected

Path 28 Row 26

	90/09/08	LM85238216235x0
	85/07/08	LM85049416335x0
30/26	73/07/22	LM8136416364500
31/26	76/06/10	LM8250516245500

Path 28 Row 27

	90/09/08	LM85238216241x0	OR
	90/07/06	LM85231816243x0	
	85/07/08	LM85049416342x0	
30/27	74/07/17	LM8172416290500	
31/27	74/08/05	LM8174316340500	

Path 28 Row 28

	91/08/26	LM85273416282x0
	85/08/25	LM85054216342x0
30/28	74/07/17	LM8172416292500

Second WRS-1 not required?

Path 28 Row 29

	91/08/26	LM85273416285x0
	85/09/26	LM85057416342x0
30/29	73/09/14	LM8141816370500

Second WRS-1 not required?

Path 28 Row 30

	92/09/29	LM85313416272x0
	85/09/26	LM85057416344x0
30/30	73/09/14	LM8140016375500

Second WRS-1 not required?

Path 28 Row 31

	92/08/28	LM85310216282x0
	84/08/14	LM84076016305x0
30/31	73/08/27	LM8140016381500

Second WRS-1 not required?

Path 28 Row 32

	92/08/28	LM85310216284x0
	84/08/14	LM84076016311x0
30/32	72/08/14	LM8102216384500

Second WRS-1 not required?

Path 28 Row 33

	92/08/28	LM85310216290x0
	86/09/13	LM85092616272x0
30/33	74/08/04	LM8174216305500

Second WRS-1 not required?

Path 28 Row 34

	92/08/28	LM85310216293x0
	84/09/07	LM85019016371x0
30/34	72/09/19	LM8105816395500

Second WRS-1 not required?

Path 28 Row 35

	92/08/28	LM85310216295x0
	86/08/28	LM85091016284x0
30/35	72/09/19	LM8105816401500

Second WRS-1 not required?

Path 28 Row 36

	92/08/28	LM85310216302x0
	85/08/09	LM85052616374x0
29/36	72/07/26	LM8100316355500
30/36	74/07/17	LM8172416324500

Path 28 Row 37

	92/08/28	LM85310216304x0
	85/08/09	LM85052616380x0
29/37	73/07/21	LM8136316353500
30/37	72/09/19	LM8105816410500

Path 28 Row 38

	92/09/29	LM85313416303x0
	84/09/07	LM85019016385x0
29/38	72/08/31	LM8103916355500
30/38	74/10/15	LM8181416304500

Path 28 Row 39

	92/08/28	LM85310216313x0
	86/07/27	LM85087816313x0
29/39	72/08/31	LM8103916361500
30/39	72/08/14	LM8102216414500

Path 29 Row 26

	90/08/30	LM85237316300x0
	85/07/31	LM85051716395x0
31/26	76/06/10	LM8250516245500
32/26	74/08/06	LM8174416392500

Path 29 Row 27

	90/07/13	LM85232516304x0
	86/07/18	LM85086916331x0
31/27	74/08/05	LM8174316340500
32/27	74/08/06	LM8174416394500

Path 29 Row 28

	90/07/13	LM85232516310x0
	84/07/20	LM84073516360x0
31/28	73/08/28	LM8140116424500
32/28	72/07/29	LM8100616484500

Path 29 Row 29

	90/07/13	LM85232516313x0
	84/08/13	LM85016516410x0
31/29	73/07/05	LM8134716435500
32/29	72/07/29	LM8100616490500

Path 29 Row 30

	90/08/30	LM85237316313x0
	84/08/29	LM85018116414x0
31/30	73/08/28	LM8140116433500

Second WRS-1 not required?

Path 29 Row 31

	91/07/16	LM85269316352x0
	84/08/13	LM85016516415x0
31/31	74/07/18	LM8172516362500

Second WRS-1 not required?

Path 29 Row 32

	90/08/30	LM85237316322x0
	84/08/29	LM85018116423x0
31/32	73/08/10	LM8138316444500

Second WRS-1 not required?

Path 29 Row 33

	92/08/19	LM85309316352x0
	86/09/20	LM85093316332x0
31/33	73/08/28	LM8140116444500

Second WRS-1 not required?

Path 29 Row 34

	92/07/18	LM85306116362x0
	86/08/03	LM85088516352x0
31/34	73/07/05	LM8134716455500

Second WRS-1 not required?

Path 29 Row 35

	91/08/01	LM85270916371x0
	86/07/18	LM85086916362x0
31/35	73/07/05	LM8134716462500

Second WRS-1 not required?

Path 29 Row 36

	92/08/03	LM85307716365x0
	86/07/18	LM85086916364x0
31/36	75/08/09	LM8219916343500

Second WRS-1 not required?

Path 29 Row 37

	92/08/03	LM85307716371x0
	85/07/31	LM85051716442x0
30/37	72/09/19	LM8105816410500
31/37	75/08/09	LM8219916350500

Path 29 Row 38

	92/08/03	LM85307716374x0
	86/07/18	LM85086916373x0
30/38	75/08/08	LM8219816294500
31/38	72/07/28	LM8100516470500

Path 30 Row 26

	92/08/10	LM85308416390x0
	85/08/07	LM85052416460x0
32/26	74/08/06	LM8174416392500
33/26	72/07/30	LM8100716533500

Path 30 Row 27

	92/08/10	LM85308416392x0
	84/08/12	LM84075816413x0
32/27	74/08/06	LM8174416394500
33/27	73/08/30	LM8140316534500

Path 30 Row 28

	92/08/10	LM85308416394x0
	86/07/25	LM85087616393x0
32/28	72/07/29	LM8100616484500
33/28	73/09/17	LM8142116534500

Path 30 Row 29

	91/08/24	LM85273216411x0
	84/08/12	LM84075816422x0
32/29	72/07/29	LM8100616490500
33/29	72/09/04	LM8104316550500

Path 30 Row 30

	91/08/24	LM85273216413x0
	84/08/12	LM84075816424x0
32/30	72/07/29	LM8100616493500
33/30	72/08/17	LM8102516551500

Path 30 Row 31

	90/09/14	LM84298216461x0
	84/08/28	LM84077416431x0
32/31	72/09/21	LM8106016500500

Second WRS-1 not required?

Path 30 Row 32

	92/09/27	LM85313216403x0
	86/09/27	LM85094016385x0
32/32	72/09/21	LM8106016503500

Second WRS-1 not required?

Path 30 Row 33

	92/09/27	LM85313216405x0
	86/09/27	LM85094016391x0
32/33	75/09/24	LM8515816231500

Second WRS-1 not required?

Path 30 Row 34

	92/09/27	LM85313216412x0
	86/09/27	LM85094016394x0
32/34	74/10/17	LM8181616403500

Second WRS-1 not required?

Path 30 Row 35

	92/09/27	LM85313216414x0
	86/09/11	LM85092416403x0
32/35	74/10/17	LM8181616405500

Second WRS-1 not required?

Path 30 Row 36

	92/09/27	LM85313216421x0
	86/09/11	LM85092416410x0
32/36	72/10/09	LM8107816522500

Second WRS-1 not required?

Path 30 Row 37

	92/10/13	LM85314816421x0
	86/10/13	LM85095616402x0
32/37	72/10/09	LM8107816524500

Second WRS-1 not required?

Path 30 Row 38

	92/10/13	LM85314816423x0
	86/10/13	LM85095616404x0
32/38	72/10/09	LM8107816531500

Second WRS-1 not required?

Path 30 Row 39

	92/10/13	LM85314816430x0
	86/10/13	LM85095616411x0
32/39	72/10/09	LM8107816533500

Second WRS-1 not required?

Path 31 Row 26

	91/08/31	LM85273916461x0
	84/08/11	LM85016316521x0
33/26	72/07/30	LM8100716533500
34/26	72/08/18	LM8102616592500

Path 31 Row 27

	91/08/31	LM85273916463x0
	84/08/11	LM85016316523x0
33/27	73/08/30	LM8140316534500
34/27	72/08/18	LM8102616594500

Path 31 Row 28

	91/08/31	LM85273916470x0
	84/08/11	LM85016316530x0
33/28	73/09/17	LM8142116534500
34/28	72/08/18	LM8102617001500

Path 31 Row 29

	92/09/02	LM85310716460x0
	84/08/27	LM85017916534x0
33/29	72/09/04	LM8104316550500
34/29	73/10/06	LM8144016592500

Path 31 Row 30

	92/09/02	LM85310716462x0
	84/08/27	LM85017916541x0
33/30	72/08/17	LM8102516551500
34/30	73/10/06	LM8144016595500

Path 31 Row 31

	92/08/01	LM85307516471x0
	84/08/11	LM85016316541x0
33/31	73/08/12	LM8138516554500
34/31	73/07/26	LM8136817014500

Path 31 Row 32

	90/08/28	LM85237116444x0
	84/08/11	LM85016316543x0
33/32	72/08/17	LM8102516560500
34/32	73/07/26	LM8136817020500

Path 31 Row 33

	92/08/01	LM85307516480x0
	86/07/16	LM85086716480x0
33/33	73/07/25	LM8136716564500
34/33	72/08/18	LM8102617021500

Path 31 Row 34

	92/08/01	LM85307516483x0
	86/07/16	LM85086716482x0
33/34	73/07/07	LM8134916572500

Second WRS-1 not required?

Path 31 Row 35

	90/09/13	LM85238716455x0
	84/08/27	LM85017916560x0
33/35	72/09/22	LM8106116573500

Second WRS-1 not required?

Path 31 Row 36

	90/08/28	LM85237116462x0
	84/08/27	LM85017916563x0
33/36	72/09/22	LM8106116575500

Second WRS-1 not required?

Path 31 Row 37

	92/06/30	LM85304316500x0
	86/08/01	LM85088316490x0
33/37	72/07/30	LM8100716581500

Second WRS-1 not required?

Path 31 Row 38

	92/07/16	LM85305916501x0
	86/07/16	LM85086716500x0
33/38	72/07/30	LM8100716584500

Second WRS-1 not required?

Path 32 Row 26

	92/08/08	LM85308216512x0
	84/07/01	LM85012216571x0
34/26	72/08/18	LM8102616592500
35/26	74/07/22	LM8172916570500

Path 32 Row 27

	91/08/22	LM85273016524x0
	84/08/10	LM84075616535x0
34/27	72/08/18	LM8102616594500
35/27	74/07/22	LM8172916573500

Path 32 Row 28

	91/08/22	LM85273016530x0
	84/08/10	LM84075616542x0
34/28	72/08/18	LM8102617001500
35/28	74/07/04	LM8171116583500

Path 32 Row 29

	92/09/09	LM85311416520x0
	85/09/06	LM85055416591x0
34/29	73/10/06	LM8144016592500
35/29	72/10/12	LM813511706450

Path 32 Row 30

	92/09/09	LM85311416523x0
	85/09/06	LM85055416594x0
34/30	73/10/06	LM8136817011500
35/30	72/08/19	LM8102717065500

Path 32 Row 31

	92/09/09	LM85311416525x0
	85/09/06	LM85055417000x0
34/31	73/10/06	LM8144017001500
35/31	72/08/19	LM8102717072500

Path 32 Row 32

	92/09/09	LM85311416531x0
	85/09/06	LM85055417003x0
34/32	73/10/06	LM8144017004500
35/32	72/08/01	LM8100917073500

Path 32 Row 33

	92/09/09	LM85311416534x0
	85/09/06	LM85055417005x0
34/33	72/08/18	LM8102617021500
35/33	74/07/04	LM8171117004500

Path 32 Row 34

	92/09/09	LM85311416540x0
	85/09/06	LM85055417011x0
34/34	72/07/31	LM8100817024500
35/34	75/07/26	LM8218516570500

Path 32 Row 35

	92/09/09	LM85311416543x0
	85/09/06	LM85093816525x0
34/35	74/10/19	LM8181816522500

Second WRS-1 not required?

Path 32 Row 36

	92/09/25	LM85313016543x0
	86/09/25	LM85093816525x0
34/36	74/10/19	LM8181816524500

Second WRS-1 not required?

Path 32 Row 37

	92/09/09	LM85311416551x0
	85/09/06	LM85055417023x0
34/37	74/10/19	LM8181816531500

Second WRS-1 not required?

Path 33 Row 26

	90/09/11	LM85238516544x0
	84/08/25	LM85017717045x0
35/26	74/07/22	LM8172916570500
36/26	74/07/23	LM8173017025500

Path 33 Row 27

	90/09/11	LM85238516550x0
	84/08/25	LM85017717051x0
35/27	74/07/22	LM8172916573500
36/27	74/09/15	LM8178417011500

Path 33 Row 28

	92/08/15	LM85308916584x0
	86/08/15	LM85089716574x0
35/28	74/07/04	LM8171116583500
36/28	73/07/10	LM8135217120500

Path 33 Row 29

	92/08/15	LM85308916590x0
	86/08/15	LM85089716580x0
35/29	73/07/09	LM8135117064500
36/29	74/07/05	LM8171217044500

Path 33 Row 30

	92/08/15	LM85308916590x0
	86/08/15	LM85089716580x0
35/30	72/08/19	LM8102717065500
36/30	74/07/05	LM8171217050500

Path 33 Row 31

	92/08/15	LM85308916592x0
	86/08/15	LM85089716583x0
35/31	72/08/19	LM8102717072500
36/31	73/08/15	LM8138817125500

Path 33 Row 32

	92/08/15	LM85308916595x0
	86/08/15	LM85089716585x0
35/32	72/08/01	LM8100917073500
36/32	73/08/15	LM8138817131500

Path 34 Row 26

	92/07/21	LM85306417040x0
	85/07/02	LM85048817110x0
36/26	74/07/23	LM8173017025500
37/26	75/07/10	LM8216917053500

Path 34 Row 27

	90/09/18	LM85239217011x0
	84/09/17	LM85020017113x0
36/27	75/09/15	LM8178417011500
37/27	74/09/16	LM8178517065500

Path 34 Row 28

	90/09/18	LM85239217014x0
	84/09/17	LM85020017115x0
36/28	73/07/10	LM8135217120500
37/28	72/09/08	LM8104717173500

Path 34 Row 29

	91/09/05	LM85274417060x0
	84/09/17	LM85020017122x0
36/29	75/09/01	LM8222216595500
37/29	72/09/08	LM8104717175500

Path 34 Row 30

	91/09/21	LM85276017063x0
	84/09/17	LM85020017124x0
36/30	75/09/01	LM8222217002500
37/30	72/09/08	LM8104717182500

Path 35 Row 26

	92/08/13	LM85308717095x0
	86/07/28	LM85087917093x0
37/26	75/07/10	LM8216917053500
38/26	73/07/12	LM8135417224500

Path 35 Row 27

	92/08/13	LM85308717101x0
	86/08/29	LM85091117084x0
37/27	74/09/16	LM8178517065500
38/27	73/07/12	LM8135417230500

Path 35 Row 28

	92/08/13	LM85308717104x0
	86/08/29	LM85091117091x0
37/28	72/09/08	LM8104717173500
38/28	74/07/25	LM8173217150500

Path 35 Row 29

	92/08/29	LM85310317104x0
	86/08/29	LM85091117093x0
37/29	72/09/08	LM8104717175500
38/29	74/09/17	LM8178617132500

Path 35 Row 30

	92/09/30	LM85313517103x0
	86/10/16	LM85095917082x0
37/30	72/09/08	LM8104717182500
38/30	74/09/17	LM8178617135500

Path 36 Row 26

	91/08/18	LM85272617170x0
	84/08/14	LM85016617231x0
38/26	73/07/12	LM8135417224500
39/26	73/09/05	LM8140917273500

Path 36 Row 27

	91/08/18	LM85272617172x0
	84/08/14	LM85016617233x0
38/27	73/07/12	LM8135417230500
39/27	73/09/05	LM8140917280500

Path 36 Row 28

	91/08/18	LM85272617174x0
	86/08/20	LM85090217154x0
38/28	74/07/25	LM8173217150500
39/28	72/08/05	LM8101317285500

Path 37 Row 26

	91/07/24	LM85270117230x0
	84/07/20	LM85014117283x0
40/26	75/08/09	LM8511217085500

Second WRS-1 not required?

Path 37 Row 27

	92/07/26	LM85306917225x0
	86/08/27	LM85090917211x0
40/27	73/09/06	LM8141017334500

Second WRS-1 not required?

Path 37 Row 28

	91/07/24	LM85270117235x0
	86/08/27	LM85090917213x0
39/28	72/08/05	LM8101317285500
40/28	73/08/01	LM8137417344500

Path 38 Row 26

	91/07/15	LM85269217290x0
	84/07/19	LM84073417305x0
41/26	72/08/07	LM8101517392500

Second WRS-1 not required?

Path 39 Row 26

	92/08/09	LM85308317344x0
	85/07/21	LM85050717415x0
42/26	74/07/29	LM8173617370500

Second WRS-1 not required?

Path 40 Row 26

	92/07/31	LM85307417405x0
	85/07/28	LM85051417480x0
43/26	72/08/27	LM8103517511500

Second WRS-1 not required?

These lists of triplicates may change in number and characteristics over time. This may be due to data being unavailable, or magnetic tapes may have failed over time in storage, or for a variety of other reasons.

Questions related to the characteristics of the triplicates may be directed to User Services at the EROS Data Center. The phone number and address are provided in the overview on page 2.

Appendix V:

Interagency Agreement (IAG) Documentation

United States Environmental Protection Agency
Washington, DC 20460

EPA

Interagency Agreement/ Amendment

Part 1 - General Information

1. EPA IAG Identification Number: DW14934750-01-4
2. Other Agency IAG ID Number (if known):
3. Type of Action: Augmentation INCR.
4. Funding Location by Region: XI
5. Program Office Abbreviation: EMSL-LV

6. Name and Address of EPA Organization
US Environmental Protection Agency
EMSL-LV, AMD/AMS
944 E.Harmon Ave., P.O. Box 93478
Las Vegas, NV 89193-3478

7. Name and Address of Other Agency
Interior Department of the
U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57198

8. Project Title: EROS Data Center: AVHRR Data/Product Support

9. EPA Project Officer (Name, Address, Telephone Number)
Lunetta, Ross S.
EMSL-LV, AMD/AMS
Las Vegas, NV 89193-3478
(702) 798-2175

10. Other Agency Project Officer (Name, Address, Telephone Number)
Lauer, Donald T., Department of the Interior
U.S. Geological Survey, EROS Data Center
Science and Applications Branch
Sioux Falls, SD 57198
(605) 594-6511

11. Project Period: 06/01/90 to 09/30/94

12. Budget Period: 10/01/91 to 09/30/93

13. Scope of Work (Attach additional sheets, as needed)

SEE ATTACHED REVISED SOW

EPA GRANTS SPECIALIST FOR THIS IAG
IS FELICIA TARVER, 202-260-4392

14. Statutory Authority for Both Transfer of Funds and Project Activities
Economy Act 1932 Amended (31 USC 1535)
Clean Air Act As Amended Sec. 327 (b) (6)

15. Other Agency Type: Federal

Funds	Previous Amount	Amount This Action	Amended Total
16. EPA Amount	917,325	10,000	927,325
17. EPA In-Kind Amount	0	0	0
18. Other Agency Amount	0	0	0
19. Other Agency In-Kind Amount	0	0	0
20. Total Project Cost	917,325	10,000	927,325

21. Fiscal Information

Program Element	FY	Appropriation	Doc. Control No.	Account Number	Object Class	Obligation/Deobligation Amt.
CC9A1E	93	683/40107	JRE	3CC926J011	25.71	10,000

EPA Form 1610-1 (Rev. 10-88) Previous editions are obsolete.

13. Scope of Work

The U.S. Geological Survey, EROS Data Center (EDC) and U.S. Environmental Protection Agency (EMSL-LV), will jointly participate in the production and evaluation of Advanced Very High Resolution Radiometer (AVHRR)- derived vegetation greeness maps and subsequent land cover mapping efforts for the 1992 growing season. Also, EDC and EMSL-LV will work jointly on the Landsat MSS North American Landscape Characterization Pathfinder (NALC) - Pathfinder Interagency Global Change project.

Since 1990, EDC has been providing EMSL-LV digital products of the AVHRR-derived data from the Conterminous U.S. and Alaska greeness mapping program. This program is continuing in 1992 with the production of greeness products of 1992 and 1989 AVHRR data from the Conterminous U.S. and 1992 AVHRR data of Alaska. EDC and the Canada Center for Remote Sensing have begun developing prototype greeness data sets of North America. EDC will provide EMSL-LV all interim and final products of North America as they become available.

EDC will continue to refine the AVHRR-derived land characterization data base of the Conterminous U.S. and provide EMSL-LV with improved land cover data sets. EDC will begin development of the North American land characterization data base and provide EMSL-LV with data as they become available.

Cooperation between EMSL-LV and EDC on the NALC-Pathfinder project is anticipated to continue well into the decade. The areas of NALC collaboration include: 1) Landsat MSS 1992 data acquisition for North America, 2) cloud-free MSS composite data processing, 3) the assembly of multiple date MSS coregistered data sets, 4) data index and archiving, and 5) the development of MSS land cover and change detection data analysis techniques. EDC will collaborate on all of the above tasks with EMSL-LV. However, EDC will concentrate on the assemblage of MSS multi-date scenes coregistered data sets, image compositing, data index and archiving, and data distribution.

Budget (FY92/3)

The following is the total FY92/3 budget under this IAG. This is the final budget distribution that reflect changes resulting from the release of Landsat MSS data distribution rights from EOSAT Corporation.

Funding Elements	FY92	FY93
Personnel (1992 AVHRR Support)	$ 39.0K	-0-
Personnel (NALC Image Compositing)	$ 39.0K	-0-
NALC Travel Support	$ 9.0K	-0-
EPA NALC Graphics/Data Support	$ 19.0K	-0-
NALC MSS Triplicate Assembly	$ 390.0K	-0-
NALC MSS Data Acq. Brokerage Assistance	$ 147.5K	-0-
NALC MSS Data Acquisition	$ 152.0K	-0-
Brazil MSS Data Acquisition (OEPER)	$ 16.6K	-0-
EPA Contribution Access to SPOT(pan.) Interagency Acquisition (OEPER/EMAP)	$ 15.0K	$ 10.0K
EPA Contribution to EROS Brazilian Retrieval of Landsat MSS from decaying HDDT's (OEPER)	$ 20.0K	-0-
Purchase of approx. 375 Landsat for Selected Locations in S.E. Asia by David Skole (OEPER)	$ 30.0K	-0-
EDC Procurement of Mexico & C. Am. Topo Maps	$ 5.225K	-0-
TOTAL FUNDING	$ 882.325K	$ 10.0K

Part II - Approved Budget

EPA IAG Identification Number

22. Budget Categories	Itemization of This Action	Itemization of Total Project Estimated Cost to Date
(a) Personnel	$ 0	$ 74,000
(b) Fringe Benefits	0	0
(c) Travel	0	9,000
(d) Equipment	0	0
(e) Supplies	0	0
(f) Procurement/Assistance	10,000	594,325
(g) Construction	0	0
(h) Other	0	250,000
(i) Total Direct Charges	$ 0	$ 917,325
(j) Indirect Costs: Rate 0.00 % Base $ 0	0	0
(k) Total (EPA Share 100.00%) (Other Agency Share 0.00 %)	$ 10,000	$ 927,325

23. Is equipment authorized to be furnished by EPA or leased, purchased, or rented with EPA funds? (Identify all equipment costing $1,000 or more) ☐ Yes ☒ No

24. Are any of these funds being used on extramural agreements? (See Item 22f) ☒ Yes ☐ No

Type of Extramural Agreement ☐ Grant ☐ Cooperative Agreement ☒ Procurement (Includes Small Purchase Order)

Contractor/Recipient Name (if known)	Total Extramural Amount Under This Project	Percent Funded by EPA (if known)
	10,000	100.00

Part III - Funding Methods and Billing Instructions

25. ☒ Funds-Out Agreement **(Note: EPA Agency Location Code (ALC) - 68010727)**

☒ Disbursement Agreement

☒ Repayment — Request for repayment of actual costs must be itemized on SF 1081 or SF 1080 and submitted to the Financial Management Center, EPA, Cincinnati, OH 45268:

☐ Monthly ☒ Quarterly ☐ Upon Completion of Work

☐ Advance — Only available for use by Federal agencies on working capital fund or with appropriate justification of need for this type of payment method. Unexpended funds at completion of work will be returned to EPA. Quarterly cost reports will be forwarded to the Financial Management Center, EPA, Cincinnati, OH 45268.

☐ Allocation Transfer-Out — Used to transfer obligational authority or transfer of function between Federal agencies. Must receive prior approval by the Office of the Comptroller, Budget Division, Budget Formulation and Control Branch, EPA Headquarters. Forward appropriate reports to the Financial Reports and Analysis Branch, Financial Management Division, PM-226F, EPA, Washington, DC 20460.

26. ☐ Funds-In Agreement

☐ Reimbursement Agreement ☐ Repayment ☐ Advance

☐ Allocation Transfer-In

Other Agency's IAG Identification Number	EPA Program Office Allowance Holder/Responsibility Center Number
Other Agency's Billing Address *(Include Agency Location Code or Station Symbol Number)*	Other Agency's Billing Instructions and Frequency

Part IV - Acceptance Conditions	EPA IAG Identification Number DW14934750-01-4

27. General Conditions

The other agency covenants and agrees that it will expeditiously initiate and complete the project for which funds have been awarded under this agreement.

28. Special Conditions *(Attach additional sheets if needed)*

See Attachment A: DBE Special Condition for Interagency Agreement

Part V - Offer and Acceptance

Note: 1) For Funds-out actions, the agreement/amendment must be signed by the other agency official in duplicate and one original returned to the Grants Administration Division for Headquarters agreements or to the appropriate EPA Regional IAG administration office within 3 calendar weeks after receipt or within any extension of time as may be granted by EPA. The agreement/amendment must be forwarded to the address cited in Item 29 after acceptance signature.

Receipt of a written refusal or failure to return the properly executed document within the prescribed time may result in the withdrawal of the offer by EPA. Any change to the agreement/amendment by the other agency subsequent to the document being signed by the EPA Action Official, which the Action Official determines to materially alter the agreement/amendment, shall void the agreement/amendment.

2) For Funds-in actions, the other agency will initiate the action and forward two original agreements/amendments to the appropriate EPA program office for signature. The agreements/amendments will then be forwarded to the appropriate EPA IAG administration office for acceptance signature on behalf of the EPA. One original copy will be returned to the other agency after acceptance.

EPA IAG Administration Office (for administrative assistance)	EPA Program Office (for technical assistance)
29. Organization/Address U.S. EPA Grants Information and Analysis Branch Grants Administration Division (PM-216F) 401 M. Street, SW Washington, DC 20460	30. Organization/Address U.S. EPA, EMSL-LV, AMD/AMS P.O. Box 93478 Las Vegas, NV 89193-3478

Certification

All signers certify that the statements made on this form and all attachments thereto are true, accurate, and complete. Signers acknowledge that any knowingly false or misleading statement may be punishable by fine or imprisonment or both under applicable law.

Decision Official on Behalf of the Environmental Protection Agency Program Office		
31. Signature	Typed Name and Title Wayne N. Marchant Director, EMSL-LV	Date
Action Official on Behalf of the Environmental Protection Agency		
32. Signature	Typed Name and Title W. Scott McMoran, Chief Grants Info. & Analysis Branch	Date
Authorizing Official on Behalf of the Other Agency		
33. Signature	Typed Name and Title Allen H. Watkins, Chief National Mapping Division	Date

DBE Interagency Agreements Special Conditions

EPA's policy requires at least 8% of its Federal funding for prime and subcontracts be awarded to businesses or other organizations owned or controlled by socially and economically disadvantaged individuals.

As a recipient of monies under this IAG, the Department of the Interior must ensure to the fullest extent possible that at least 8% of funds for prime or subcontracts and subgrants for services are made available to businesses owned or controlled by socially and economically disadvantaged individuals, women-owned businesses, and Historically Black Colleges and Universities. (DBE)

The Department of Interior must submit a report to EPA showing the total extramural funds awarded and the amount and percentage of extramural funds awarded to DBEs by November 15, 1992. Reports should be submitted to:

Office of Small and Disadvantaged
Business Utilization (A-149C)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

United States Environmental Protection Agency Washington DC 20460 — **EPA** Interagency Agreement / Amendment — Part I - General Information	1. EPA / IAG Identification Number: DW14935881-01-0	4. Funding Location by Region: XI
	2. Other Agency ID Number:	5. Program Office Abbreviation: EMSL-LV
	3. Type of Action: NEW	

6. Name and Address of EPA Organization	7. Name and Address of Other Agency
EMSL-LV, AMD/AMS 944 E. HARMON AVE. P.O. BOX 93478 LAS VEGAS, NV 89193-3478	INTERIOR DEPARTMENT OF THE USGS, EROS DATA CENTER MUNDT FEDERAL BUILDING SIOUX FALLS, SD 57198

8. Project Title EROS DATA CENTER AVHRR/NALC/PRODUCT SUPPORT

9. EPA Project Officer (Name, Address, Telephone Number)	10. Other Agency Project Officer (Name, Address, Telephone Number)
ROSS S. LUNETTA EMSL-LV, AMD/AMS P.O. BOX 93478 LAS VEGAS, NV 89193-3478 (702) 798-2175	DONALD T. LAUER, DOI, USGS EROS DATA CENTER, MUNDT FEDERAL BLDG. SCIENCE & APPLICATIONS BRANCH SIOUX FALLS, SD 57198 (605) 594-6511
11. Project Period 10/01/92 to 09/30/94	**12. Budget Period** 10/01/92 to 09/30/94

13. Scope of Work (Attach additional sheets, as needed)

See Attached SOW

THE EPA GRANTS SPECIALIST FOR THIS
IAG IS FELICIA TARVER, 202-260-4392

COMMITMENT VERIFIED.
Date. 1/11/92 By. [illegible]

FEB 1 1993

14. Statutory Authority for Both Transfer of Funds and Project Activities	15. Other Agency Type
ECONOMY ACT OF 1932 AS AMENDED	FEDERAL

FUNDS	PREVIOUS AMOUNT	AMOUNT THIS ACTION	AMENDED TOTAL
16. EPA Amount	0	416,000	
17. EPA In-Kind Amount	0	0	
18. Other Agency Amount	0	0	
19. Other Agency In-Kind Amount	0	0	
20. Total Project Cost	0	416,000	

21. Fiscal Information

Program Element	FY	Appropriation	Doc. Control No.	Account Number	Object Class	Obligation/Deoblig. Amt.
CNRA1E	93	683/40107	JRS006	3CNR26J012	25.71	416,000

13. Scope of Work

The U.S. Geological Survey, EROS Data Center (EDC) and U.S. Environmental Protection Agency (EMSL-LV), will jointly participate in the production and evaluation of Advanced Very High Resolution Radiometer (AVHRR)- derived vegetation greenness maps for the 1993 growing season and subsequent land cover mapping efforts for the 1992 and 1993 growing seasons. Also, EDC and EMSL-LV will work jointly on the Landsat MSS North American Landscape Characterization Pathfinder (NALC) - Pathfinder Interagency Global Change project.

Since 1990, EDC has been providing EMSL-LV digital products of the AVHRR-derived data from the Conterminous U.S. and Alaska greenness mapping program. This program is continuing in 1993 with the production of greenness products of 1992 and 1993 AVHRR data from the Conterminous U.S. and Alaska. EDC and the Canada Center for Remote Sensing have developed prototype greenness data sets of North America. The production of greeness data sets for North America will continue for the 1993 growing season. EDC will provide EMSL-LV all interim and final products of North America as they become available.

EDC will continue to refine the AVHRR-derived land characterization data base of the Conterminous U.S. and provide EMSL-LV with improved land cover data sets. EDC will continue development of the North American land characterization 1992 data base and provide EMSL-LV with data as they become available.

Cooperation between EMSL-LV and EDC on the NALC-Pathfinder project is anticipated to continue well into the decade. The areas of NALC collaboration include: 1) cloud-free MSS composite data processing, 2) the assembly of multiple date MSS coregistered data sets, 3) data index and archiving, and 4) the development of MSS land cover and change detection data analysis techniques. EDC will collaborate on all of the above tasks with EMSL-LV. However, EDC will concentrate on the assemblage of MSS multi-date scenes coregistered data sets, image compositing, data index and archiving, and data distribution.

Budget (FY93)

The following is the total FY93 budg under this IAG.

Funding Element	Total FY93 Funds
1993 AVHRR Support	$ 45.0K
Personnel (Image Compositing)	$ 45.0K
NALC Travel Support	$ 10.0K
EPA Graphics/Data Support	$ 15.0K
MSS Multidate Scene Coregistration	$ 291.0K
Pecora Symposium EPA Sponsorship	$ 10.0K
TOTAL FY92 FUNDING	$ 416.0K

Part II - Approved Budget		EPA IAG Identification Number DW14935881-01-0
22. Budget Categories	Itemization of This Action	Itemization of Total Project Estimated Cost to Date
(a) Personnel	381,000	381,000
(b) Fringe Benefits	0	0
(c) Travel	10,000	10,000
(d) Equipment	0	0
(e) Supplies	0	0
(f) Procurement / Assistance	10,000	10,000
(g) Construction	0	0
(h) Other Graphics Support	15,000	15,000
(i) Total Direct Charges	416,000	416,000
(j) Indirect Costs: Rate 0.00 % Base $ 0.	0	0
(k) Total: (EPA Share: 100.00 %) (Other Agency Share 0.00%)	416,000	416,000

23. Is Equipment authorized to be furnished by EPA or leased, purchased, or rented with EPA funds? ☐ Yes ☒ No
(Identify all equipment costing $1000 or more.)

24. Are any of these funds being used on extramural agreements? (See Item 22f.) ☒ Yes ☐ No

Type of extramural agreement ☐ Grant ☐ Cooperative Agreement ☒ Procurement (includes Small Purchase Order)

Contractor / Recipient Name (if known)	Total Extramural Amount under this Project	Percent Funded by EPA (if known)
TBD (Pecora Symposium)	10,000	100.00

Part III - Funding Methods and Billing Instructions

25.

☒ Funds-Out Agreement (Note: EPA Agency Location Code (ALC) - 68010727)

☒ Disbursement Agreement

☒ Repayment — Request for repayment of actual costs must be itemized on SF-1080 and submitted to the Financial Management Office, Cincinnati, OH 45268:
☐ Monthly ☒ Quarterly ☐ Upon Completion of Work

☐ Advance — Only available for use by Federal agencies on working capital fund or with appropriate justification of need for this type of payment method. Unexpended funds at completion of work will be returned to EPA. Quarterly cost reports will be forwarded to the Financial Management Center, EPA, Cincinnati, OH 45268.

☐ Allocation Transfer-Out — Used to transfer obligational authority or transfer of function between Federal agencies. Must receive prior approval by the Office of the Comptroller, Budget Division, Budget Formulation and Control Branch, EPA Hdqtrs. Forward appropriate reports to the Financial Reports and Analysis Branch, Financial Management Division, PM-226F, EPA, Washington, DC 20460.

26. ☐ Funds-In Agreement

☐ Reimbursement Agreement ☐ Repayment ☐ Advance

☐ Allocation Transfer-In

Other Agency's IAG Identification Number	EPA Program Office Allowance Holder/Resp. Center No. 26J
Other Agency's Billing Address *(Include ALC or Station Symbol Number)*	Other Agency's Billing Instruction and Frequency

Part IV - Acceptance Conditions

EPA IAG Identification Number
DW14935881-01-0

27. General Conditions

The other agency covenants and agrees that it will expeditiously initiate and complete the project for which funds have been awarded under this agreement.

28. Special Conditions *(Attach additional sheets if needed)*

See Attached: DBE Special Condition for Interagency Agreement

Part V - Offer and Acceptance

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EPA IAG Administration Office (for administrative assistance)	EPA Program Office (for technical assistance)
29. Organization/Address U.S. EPA Grants Information and Analysis Branch Grants Administration Division (PM-216F) 401 M Street, SW Washington, DC 20460 [illegible] MUST BE [illegible] TO THIS OFFICE	30. Organization/Address U.S. EPA, EMSL-LV, AMD/AMS P.O. Box 93478 Las Vegas, NV 89193-3478

Certification

All signers certify that the statements made on this form and all attachments thereto are true, accurate, and complete. Signers acknowledge that any knowingly false or misleading statement may be punishable by fine or imprisonment or both under applicable law.

Signature	Typed Name and Title	Date
Decision Official on Behalf of the Environmental Protection Agency Program Office		
31 Signature: Wayne N Marchant	Wayne N. Marchant Director, EMSL-LV	12/14/92
Action Official on Behalf of the Environmental Protection Agency		
32. Signature: [signature]	W. Scott McMoran, Chief Grants Info. & Analysis Branch	/ /
Authorizing Official on Behalf of the Other Agency		
33. Signature: Allen H. Watkins	Allen H. Watkins, Chief National Mapping Division	2-11-93

DBE Interagency Agreements Special Conditions

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The Department of the Interior must submit a report to EPA showing the total extramural funds awarded and the amount and percentage of extramural funds awarded to DBEs by November 15, 1993. Reports should be submitted to:

Office of Small and Disadvantaged
Business Utilization (A-149C)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

EPA-EOSAT 1992 LANDSAT MSS DATA ACQUISITION AGREEMENT

To satisfy EPA's requirement to have MSS data acquired, and permit EPA the flexibility to purchase multiple scenes of cloud-prone locations, EPA proposes the following conditions for 1992 MSS data collection:

o The EPA's 1992 Landsat MSS data purchases will be accomplished through the EROS Data Center (EDC) Federal Government Brokerage Agreement. The EPA path / row and acquisition windows are being provided to EDC for transmittal to EOSAT.

o EOSAT will utilize its best efforts to provide MSS data collects to meet EPA requirements. This includes negotiating with foreign receiving stations to provide MSS data for EPA's projects.

o EOSAT agrees to collect Landsat MSS data on a continual basis for the conterminous U.S., Mexico, and portions of Central America and the Caribbean that are within the collection range of the Norman, Oklahoma receiving station, starting from the time the Norman station becomes operational, until the conclusion of the 1992 growing season.

o EPA agrees to purchase a minimum of one MSS scene at 30% or less cloud cover for each of the EPA specified path / rows collected by the Norman receiving station during the 1992 growing season. Cloud cover determinations will be based on the percent cloud cover over land areas. Cloud cover will be determined by the visual inspection of image film products at EROS Data Center (EDC) by EPA or EPA's designated representative at EDC. Cirrus clouds will be included in the percent cloud cover determinations.

o For those path / row scenes requested by EPA that require TDRSS acquisitions, EPA agrees to purchase all MSS data having 30% or less cloud cover, collected within EPA specified acquisition windows. EPA has the option to close the TDRSS acquisition windows for specific path / rows by notifying EOSAT at least seven days prior to the next scheduled acquisition. Notification will be via FAX by EPA or its EDC designate.

o For the EPA specified path / rows, EPA may purchase any MSS scene meeting the cloud cover specification of 30% or less at $1,000.00 per initial scene and $500.00 per scene for all subsequent scenes of the same path/row. If for a given path / row there is no scene meeting the 30% cloud cover specification, EPA may, at its option, purchase any MSS scenes collected within EPA's specified acquisition window at $500.00 per scene.

o EPA intends to purchase approximately $ 520,000.00 of Landsat MSS data by December 31, 1992. All data purchases are subject to the availability of government funds and the availability of MSS data for the EPA specified path / rows and acquisition windows.

Appendix VI:

Mexico Worksheet for Acquisition and Determining Temporal Windows for Acquisition of Remotely Sensed Imagery

Mexico Worksheet
(by Path / Row)
January 31, 1992

Path/Row	Phenological Window	Cloud Window	Date of '86 Coverage
24/47	Jul-Sep	Mar-May	N/A
24/48	N/A	Feb-Apr	N/A
24/49	N/A	Jan-Mar	Mar/Apr
25/46	N/A	N/A	N/A
25/47	N/A	Feb-Apr	Mar/Apr
25/48	Jul-Sep	Feb-Apr	Mar/Apr
25/49	N/A	Feb-Apr	Mar/Apr/May
26/43	N/A	N/A	N/A
26/44	Jun-Aug	Jan-Mar	N/A
26/45	N/A	N/A	N/A
26/46	Jun-Aug	Feb-Apr	May
26/47	Jun-Aug	Jan-Mar	Mar/Apr
26/48	Jun-Aug	Jan-Mar	Mar/Apr
27/42	N/A	Jun-Aug	N/A
27/43	N/A	N/A	Mar
27/44	Jun-Aug	N/A	Mar
27/45	Jul-Sep	Jan-Mar	Mar
27/46	Jul-Sep	Jan-Mar	Mar
27/47	Jun-Aug	Jan-Mar	Mar
27/48	Jun-Aug	Jan-Mar	Mar
28/41	N/A	Jun-Sep	Apr
28/42	N/A	N/A	Apr
28/43	N/A	Apr-Jun	Apr
28/44	N/A	Mar-May	Apr
28/45	Jun-Aug	Feb-Apr	Apr
28/46	Jun-Aug	Mar-May	Apr
28/47	Jun-Aug	Feb-Apr	Apr
29/40	N/A	N/A	Mar
29/41	N/A	N/A	Mar
29/42	N/A	Jun-Aug	Mar
29/43	N/A	Apr-Jun	Mar
29/44	Jul-Sep	Mar-May	Mar
29/45	Jul-Sep	Mar-May	Mar
29/46	Jul-Sep	Mar-May	Mar
29/47	Jul-Sep	Feb-Apr	Mar
30/40	N/A	N/A	Mar
30/41	N/A	Apr-Jun	Mar
30/42	N/A	Apr-Jun	Mar
30/43	N/A	Apr-Jun	Mar
30/44-	N/A	Mar-May	Mar
30/45	N/A	Feb-Apr	Mar
30/46	N/A	Mar-May	Mar
31/40	Jul-Sep	Mar-May	N/A

31/41	Jul-Sep	Apr-Jun	Mar
31/42	N/A	Apr-Jun	Mar
31/43	N/A	Jan-Mar	Mar
31/44	N/A	Nov-Jan	Mar
*32/39	N/A	Feb-Apr	Apr
*32/40	N/A	Feb-Apr	Apr
*32/41	N/A	Feb-Apr	Apr
*32/42	N/A	Feb-Apr	Apr
*32/43	N/A	Nov-Feb	Apr
33/39	Jul-Sep	Apr-Jun	Mar
33/40	Jul-Sep	Apr-Jun	Mar
33/41	N/A	Feb-Apr	Mar
33/42	Jul-Sep	Apr-Jun	Mar
33/43	Jul-Sep	Apr-Jun	Mar
33/44	N/A	Mar-May	Mar
34/39	N/A	Mar-May	Mar
34/40	N/A	Mar-May	Mar
34/41	Jul-Sep	Mar-May	Mar
34/42	Jul-Sep	Mar-May	Mar
34/43	N/A	Mar-May	Mar
34/44	N/A	Mar-May	Mar
35/39	N/A	Apr-Jun	N/A
35/40	Aug-Oct	Apr-Jun	N/A
35/41	Aug-Oct	Apr-Jun	N/A
35/42	N/A	Apr-Jun	Apr
35/43	N/A	Apr-Jun	Apr
36/39	N/A	Apr-Jun	Mar
36/40	N/A	Apr-Jun	Mar
36/41	N/A	Apr-Jun	Mar
36/42	N/A	May-Jul	Mar

* Scene exists for March 1991, with less than 10 % clouds.

Determining Temporal Windows for Acquisition of Remotely Sensed Imagery Through the use of a Decision Support System.

Hypothesis: The addition of spatio-temporal variables into the acquisition window selection process will aid decision makers in successful image acquisition, and enhance the utility of the data acquired.

Background:

- Global and continental studies using remotely sensed data involve acquisition of numerous images.

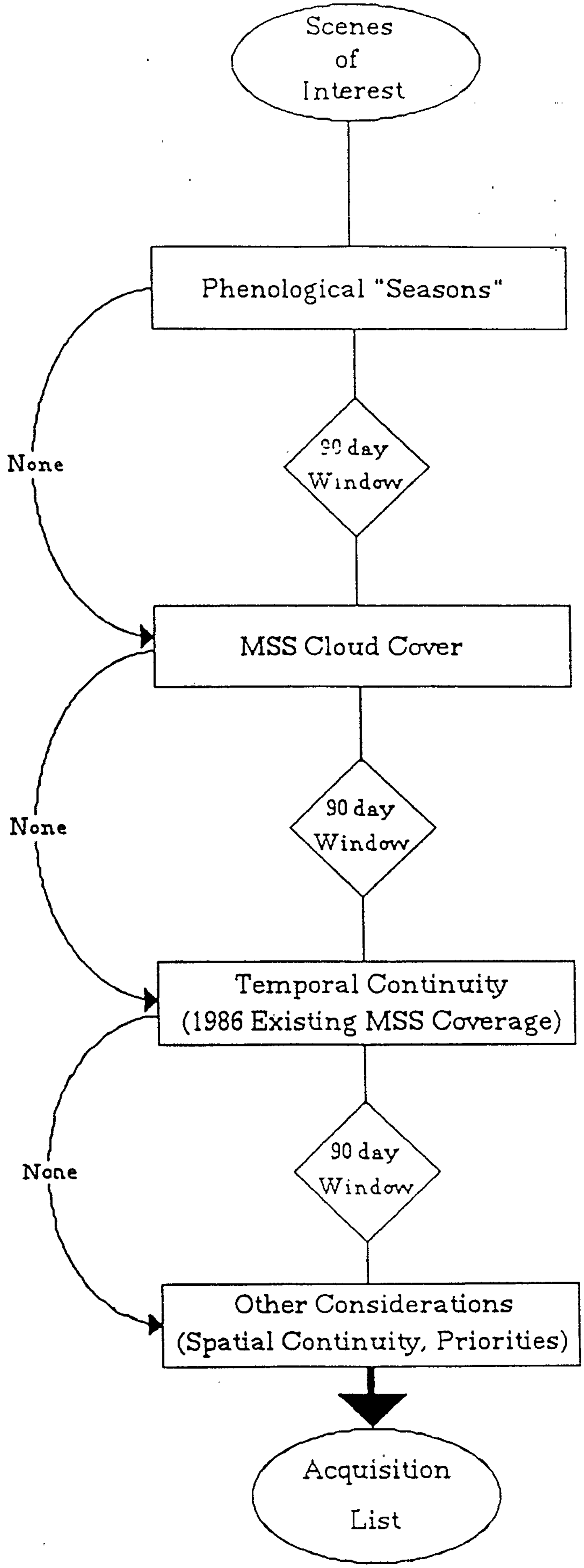
- Temporal variations in surface and atmospheric parameters can strongly influence the utility of the data.

- Application will determine which variables are critical to the success of a particular project.

- Current technology relies on intuitive and qualitative skills of the mission planner.

Approach:

- An understanding of the temporal and spatial variance relating to a region of interest is crucial to mission planning.
- The significance of any particular variable should be incorporated into the acquisition strategy.
- A Decision Support System (DSS) is a specific set of application tools designed to involve the Decision Maker interactively in the solution process.
- A Spatio-Temporal DSS incorporating the appropriate parameters, with an intuitive interface, would provide a framework for determining acquisition strategies.



Scenes of Interest
Phenological "Seasons"
None
90 day Window
MSS Cloud Cover
None
90 day Window
Temporal Continuity (1986 Existing MSS Coverage)
None
90 day Window
Other Considerations (Spatial Continuity, Priorities)
Acquisition List

Appendix VII:

NALC / GCRP Coordination / Collaboration Documents

NALC / GCRP Coordination / Collaboration

Mexico

NALC Task:

Delivery of standard and modified NALC products focused on humid tropical forested regions, in particular Mexico

GCRP Task:

Characterize changing land cover and land use and forest types in Southeastern Mexico

GCRP Contact:

Point of contact is Michael A. Cairns, EPA-ERL-C
Phones: Cairns, 430-4777 or 503-754-4777 FAX -4799

GCRP Goals:

A goal of ERL-C is assess terrestrial biosphere management options as they influence land cover, carbon pools and feedback to atmospheric conditions. To assist these efforts it is desirable to supply good land cover and land use (LC/LU) images and tabular data for areas of interest. These data will be useful in calculations of carbon pool, change in the pool or carbon flux, and for model calibration and verification activities. The current and past condition, and change in these carbon pools are significant information for the charge of evaluating natural and human-induced atmospheric conditions and their affects on ecosystems. This effort can support the understanding of feedbacks of change in land surface characteristics on atmospheric conditions.

Estimates of total land cover and change in cover will be useful in calculations of carbon pool, change in the pool or carbon flux, and for model calibration and verification activities. Quantification of current and past condition, and change in these carbon pools is significant in evaluating natural and human-induced influences on forests. This effort also supports the understanding of feedbacks from change in terrestrial landscapes on atmospheric conditions, as well as having utility in planning of substitutes for fossil fuels.

Use of remote sensor data and the objectives of North American Landscape Characterization (NALC) can supply the LC/LU data and other products. LC/LU data can be linked with management information to obtain variables and develop quantities for land use descriptors including: total forest area, commercial forests, agroforest systems, pastures, total area of agricultural lands, urban areas, park and preserves, and other land cover/land uses.

Early work on data sets have been slated for the Southern and Southeastern portions of Mexico. Coordination with ERL-C has prioritized the states of Chiapas, Quintana Roo, Campeche, and Tabasco for early data acquisition and analyses.

NALC Applications (Standard Products):

The standard products that apply to this work element would be land cover/land use images and tabular data, and evaluations of change.

NALC Applications (Modified Products):

NALC data products and analyses will provide assistance with characterizing and quantifying certain variables. These may include optimization of images for detection of land use conditions such as agroforestry, natural regeneration, and increase sensitivity to forest species composition. Analysis of change induced by fire, pestilence, and weather is necessary, and the management practices subsequent to the event would be of interest. General land use practices may be derived from NALC remote sensor data.

Scheduling for Deliveries of Standard Products:

Current NALC scheduling calls for the above products to be delivered in calendar years 1995 for Mexico, the Caribbean, Chesapeake Bay Watershed, and Central America. Alaska and Western US areas will be available in 1996. In 1997 the midwest and Great Plains and Eastern-Southern US will be available.

Potential Schedule for Modified NALC Products:

The above issues may be addressed in preliminary tests of the NALC program. The levels of sensitivity can be evaluated, and suggested modified products could be generated in support of GCRP. The timeframe would be the same from the standard products.

Proposed Coordination Action/Schedule:

Much of this effort will involve production of data sets and standard and modified products by Cooperators. Hence, it would be desirable to collaborate on Cooperator tasks to insure that the products of interest are addressed early in the delivery timeframes, and that modified products of interest to GCRP will generated. In the case of the Mexico effort, it would be desirable to meet with the Cooperators soon to develop plans. Potential cooperators include the Institute of Geography at the National Autonomous University of Mexico.

NALC / GCRP Coordination / Collaboration

Forests

NALC Task:

Delivery of standard and modified NALC products focused on forested regions of the US

GCRP Task:

Potential of global forested and agroforested lands to sequester and conserve carbon

GCRP Contact:

Points of contacts are Robert Dixon and Jack Winjum, EPA-ERL-C
Phones: Dixon, 430-4772 or 503-754-4772 FAX -4799

GCRP Goals:

The goal of ERL-C is to evaluate global forest management practices and to determine the potential for management options for conservation of carbon and sequestration in tropical, temperate and boreal forests. These efforts can be facilitated by supplying good land cover and land use (LC/LU) images and tabular data for areas of interest. These efforts would include evaluations of change in land cover due to natural phenomena and through human activities. These data can be combined with information on management practices, and be used to study the forest related management options in a given region.

Estimates of land cover and change in cover will be useful in calculations of carbon pool, change in the pool or carbon flux, and for model calibration and verification activities. Quantification of current and past condition, and change in these carbon pools is significant information for evaluating natural and human-induced influences on forests. This effort also supports the understanding of feedbacks from change in terrestrial landscapes on atmospheric conditions, as well as having utility in planning of substitutes for fossil fuels.

Use of remote sensor data and the objectives of North American Landscape Characterization (NALC) can supply the LC/LU data and other products. Early work on data sets has been slated for portions of the Pacific Northwest, Chesapeake Bay and for a study area in Alaska. These efforts will address: a) capability to detect land cover classes of interest, and b) ability to detect change in land cover and quantify that change at the scale of interest.

Later needs for satellite derived data include the greater US Pacific Northwest region with emphasis on forested areas, the Canadian Pacific Northwest regions, and the trans-boreal portions of Canada and Alaska.

NALC Applications (Standard Products):

The standard products that apply to this work element would be land cover/land use images and tabular data, and evaluations of change.

NALC Applications (Modified Products):

Potential areas of NALC data analysis assistance include optimization of images for detection of land use conditions such as agroforestry, natural regeneration, and increase sensitivity to forest species composition. Analysis of change induced by fire, pestilence, and weather is necessary, and the management practices subsequent to the event would be of interest. General land use practices may be derived from remote sensor data.

Scheduling for Deliveries of Standard Products:

Current NALC scheduling calls for the above products to be delivered in calendar years 1995 for Mexico, the Caribbean, Chesapeake Bay Watershed, and Central America. Alaska and Western US areas will be available in 1996. In 1997 the midwest and Great Plains and Eastern-Southern US will be available.

Potential Schedule for Modified NALC Products:

The above issues may be addressed in preliminary tests of the NALC program. The levels of sensitivity can be evaluated, and suggested modified products could be generated in support of GCRP. The timeframe would be the same from the standard products.

Proposed Coordination Action/Schedule:

Much of this effort will involve production of data sets and standard and modified products by Cooperators. Hence, it would be desirable to collaborate on Cooperator tasks to insure that the products of interest are addressed early in the delivery timeframes, and that modified products on interest to GCRP will generated.

NALC / GCRP Coordination / Collaboration

Tropical Forests

NALC Task:

Delivery of standard and modified NALC products focused on tropical regions

GCRP Task:

Characterize changing land cover and land use and forest types in humid tropical regions of interest in the NALC area of operations including Mexico, the Caribbean and Central America

GCRP Contact:

The point of contact is Michael A. Cairns, EPA-ERL-C. A number of other EPA groups and NASA, and others are interested in the results of this effort.
Phones: Cairns, 430-4777 or 503-754-4777 FAX -4799

GCRP Goal:

The goal is to determine the quantity of tropical forests and the rate of conversion to other land uses. These data are valuable for estimating the current abundance of carbon sequestered in the regions, and allow better model inputs and calibration and verification. The determination of change in land cover and land use (LC/LU) will also assist in the estimation of carbon pool and the flux or dynamics of the pool.

Use of remote sensor data will supply a number of useful data or information. These would include LC/LU, detection of change in LC/LU, and potential use of remote sensor data as input to habitat or resource quality models.

Pilot studies and production of standard NALC product will occur on tropical forest areas within North America. A separate effort in Brazil will be conducted under the Deforestation Monitoring program. The regions for early attention will include the states of Southern or Southeast Mexico, the Atlantic Forest region of Brazil, the island of Hispaniola, and other Caribbean islands.

Early work on data sets have been slated for the Southern and Southeastern portions of Mexico. Coordination with ERL-C has prioritized the states of Chiapas, Quintana Roo, Campeche, and Tabasco for early data acquisition and analyses.

NALC Applications (Standard Products):

The standard products that apply to this work element would be land cover/land use images and tabular data, and evaluations of change. Unprocessed data and standard image products may also be useful.

NALC Applications (Modified Products):

NALC data products and analyses will provide assistance with characterizing and quantifying certain variables. These may include optimization of images for detection of change in land use conditions such as forest harvesting and forest regeneration. Analysis of change induced by fire, pestilence, and weather is necessary, and the management practices subsequent to the event would be of interest.

Scheduling for Deliveries of Standard Products:

Current NALC scheduling calls for the above products to be delivered in calendar years 1995 for Mexico, the Caribbean, Chesapeake Bay Watershed, and Central America. Alaska and Western US areas will be available in 1996. In 1997 the midwest and Great Plains and Eastern-Southern US will be available.

Potential Schedule for Modified NALC Products:

The above issues may be addressed in preliminary tests of the NALC program. The levels of sensitivity can be evaluated, and suggested modified products could be generated the data production work by Cooperators in support of GCRP. The timeframe would be the same from the standard products.

Proposed Coordination Action/Schedule:

Early work has been slated for this activity in Brazil, Mexico, the Caribbean, and Central America. It would be desirable to communicate on a regular basis, to facilitate exchange of information.

Much of this effort will involve production of data sets and standard and modified products by Cooperators. Hence, it would be desirable to collaborate on Cooperator contracting issues to insure that the products of interest are addressed early in the delivery timeframes, and that modified products of interest to GCRP researchers will be generated.

NALC / GCRP Coordination / Collaboration

Atmospheric Trace Gases and Land Cover

NALC Task:

Delivery of standard and modified NALC products focused on land cover and land cover changes for the Southeastern US.

GCRP Task:

Characterize changing agricultural land cover types and how they may influence atmospheric trace gases

GCRP Contact:

Point of contact is Lee Mulkey, EPA-ERL-A

GCRP Goals:

A goal of ERL-A is assess terrestrial biosphere management options as they influence land cover, atmospheric trace gases such as carbon and methane, and feedbacks to atmospheric conditions. To assist these efforts it is desirable to supply good land cover and land cover change images and tabular data for areas of interest. These data will be useful in calculations of carbon pool, change in the pool or carbon flux, evaluations of sources/sinks of methane and nitrous oxide, and for model calibration and verification activities. The current and past condition, and change in these land cover are significant information for the charge of evaluating natural and human-induced atmospheric conditions and their affects on ecosystems. This effort can support the understanding of feedbacks of change in land surface characteristics on atmospheric conditions.

Use of remote sensor data and the objectives of North American Landscape Characterization (NALC) can supply the land cover and change in land cover data and other products. These data can be linked with management information to obtain variables and develop quantities for land use characteristics including: total agricultural area and change in area, commercial farms and general crop types, agroforest systems, conservation reserve areas, urban areas, park and preserves, and other land cover/land uses.

Early work on data sets have been slated for the Southern and Southeastern portion of the US. Coordination with ERL-A will prioritize the states of interest for early data acquisition and analyses.

NALC Applications (Standard Products):

The standard products that apply to this work element would be land cover/land use images and tabular data, and evaluations of change.

NALC Applications (Modified Products):

NALC data products and analyses will provide assistance with characterizing and quantifying certain variables. These may include optimization of images for detection of land cover conditions such as agricultural areas and change in these areas, conservation research program areas, and wetland areas. Analysis of change induced by land cover conversion, fire, pestilence, and weather is necessary, and the land cover change subsequent to the event would be of interest.

Scheduling for Deliveries of Standard Products:

Current NALC scheduling calls for the above products to be delivered in calendar year 1997, when the midwest and Great Plains and Eastern-Southern US will be available.

Potential Schedule for Modified NALC Products:

The above issues may be addressed in preliminary tests of the NALC program. The levels of sensitivity can be evaluated, and suggested modified products could be generated in support of GCRP. The timeframe would be the same from the standard products.

Proposed Coordination Action/Schedule:

Much of this effort will involve production of data sets and standard and modified products by Cooperators. Hence, it would be desirable to collaborate on Cooperator tasks to insure that the products of interest are addressed early in the delivery timeframes, and that modified products of interest to GCRP will generated.

NALC / GCRP Coordination / Collaboration

Remote Sensor Methods Development for Identification of Methane Sources

NALC Task:

Delivery of standard and modified NALC products focused on wetland and agricultural regions of selected areas of the US and North America

GCRP Task:

Calibration and verification of models of atmospheric trace gases in particular methane using detail land cover and land cover change data

GCRP Contact:

Point of contacts are Lee Mulkey and Richard Zepp, EPA-ERL-A

GCRP Goals:

The goal of ERL-A is to evaluate the influence of agricultural inputs, outputs and wastes that alter atmospheric concentrations of trace gases, and study how these gas flux influence global climatic conditions and evaluate feedbacks to climate. These efforts can be facilitated by supplying good land cover data, NDVI or biomass images, and land cover change data for areas of interest. These data could assist in evaluating the role of change in agricultural or wetland management practices as they influence natural phenomena such as atmospheric and terrestrial fluxes of methane.

Estimates of land cover and change in cover will be useful in calculations of methane flux, and for model calibration and verification activities. Quantification of current and past land cover condition, and change in these conditions is significant in evaluating natural and human-induced influences on landscape. This effort also supports the understanding of feedbacks from change in terrestrial landscapes to atmospheric conditions, as well as having utility in planning of alternative management practices.

Use of remote sensor data and the objectives of North American Landscape Characterization (NALC) can supply the land cover and change in land cover data, and other products. Early work on data sets has been slated for portions of the US and North America. These efforts will address: a) capability to detect land cover classes of interest, and b) ability to detect change in land covers such as agricultural type and wetlands.

NALC Applications (Standard Products):

The standard products that apply to this work element would be land cover images, tabular data, and evaluations of land cover change.

NALC Applications (Modified Products):

Potential areas of NALC data analysis assistance include optimization of images for detection of land cover conditions such as agricultural crop composition and wetland growth structure (shrub vs. tree wetlands) and pattern. Analysis of change induced by fire and weather is necessary, and regeneration subsequent to the event would be of interest.

Scheduling for Deliveries of Standard Products:

Current NALC scheduling calls for the above products to be delivered in calendar year 1997 for the midwest and Great Plains and Eastern-Southern US.

Potential Schedule for Modified NALC Products:

The above issues may be addressed in preliminary tests of the NALC program. The levels of sensitivity can be evaluated, and suggested modified products could be generated in support of GCRP. The timeframe would be the same from the standard products.

Proposed Coordination Action/Schedule:

Much of this effort will involve production of data sets and standard and modified products by Cooperators. Hence, it would be desirable to collaborate on Cooperator tasks to insure that the products of interest are addressed early in the delivery timeframes, and that modified products on interest to GCRP will generated.

NALC / GCRP Coordination / Collaboration

Trans-Boreal/ Former Soviet Union

NALC Task:

Delivery of standard and modified NALC products focused on pilot efforts to characterize land cover / land use in Alaska. Identify sources to obtain additional remote sensor-derived data on land cover or NDVI for areas in the former Soviet Union

GCRP Task:

Characterize the quantity and variety of land cover in the former Soviet Union and Trans-Boreal ecosystem, and determine change, and utilize the data in modeling of carbon and methane flux

GCRP Contact:

The points of contact are Jeff Lee of ERL-C, and Chris Elvidge of ORD/DRI. There are a variety of parties involved in the data generation and in development of products. Their are also a number of end users of the data. In particular, Ted Vinson of Oregon State University would be interested in land cover information of the former Soviet Union. This would assist his data collection and modeling efforts related to carbon budget.

Phones: Lee, 430-4634 or 503-754-4634 FAX -4799

GCRP Goals:

A number of parties are involved in the Pathfinder activities related to boreal forests. A goal is to evaluate the carbon budget of these areas, because they sequester considerable carbon and potentially can be a large source and/or sink depending on management and climate conditions. The inventory these land covers and use results in modeling of carbon pool and flux requires a remote sensor experiment.

Use of remote sensor data can potentially supply location and extent of land covers. Use of multiple date images will allow the evaluation of change in land covers such as deforestation. These analyses will also supply information on natural events that can forest morbidity or mortality. Event include fires, certain diseases, windthrow from tornados or hurricane, volcanic eruption, and other events.

The Trans-Boreal effort is a continuing one and products will ultimately provide detail valuable to global change analysis efforts. Initial products include AVHRR bi-weekly composites of selected areas, and region area composites by year.

NALC Applications (Standard Products):

The standard products that apply to this work element would be land cover/land use images and tabular data, and evaluations of change. Unprocessed data and standard image products may also be useful. These products would be used to study the capability of remote sensor input, and would utilize NALC products from Alaska and Boreal Canada.

NALC Applications (Modified Products):

NALC data products and analyses will provide assistance with characterizing and quantifying certain variables. These may include optimization of images for detection of change in extent of land covers due to forest harvesting. Analysis of change induced by fire, pestilence, and weather is necessary, and the management practices subsequent to the event would be of interest.

Scheduling for Deliveries of Standard Products:

Current NALC scheduling calls for the above products to be delivered beginning in calendar year 1995 for pilot studies of interest. Data for Alaska will be available in the 1995 timeframe, also.

Potential Schedule for Modified NALC Products:

The above issues may be addressed in preliminary tests of the NALC program. The levels of sensitivity can be evaluated, and suggested modified products could be generated the data production work by Cooperators in support of GCRP. The timeframe would be the same from the standard products.

Products from other Landsat Pathfinder experiments or AVHRR Pathfinder experiment will become available, and will be obtained the facilitate the evaluation of conditions in the former Soviet Union.

Proposed Coordination Action/Schedule:

It would be desirable to coordinate activities with the other Pathfinder and Trans-Boreal initiative to insure early access to products of interest.

NALC / GCRP Coordination / Collaboration

Rice Growing Areas

NALC Task:

Delivery of standard and modified NALC products focused on rice growing areas of the US, and identify points of contact to obtain additional remote sensor-derived data on rice growing areas

GCRP Task:

Characterize the quantity of rice growing lands and determine change, and utilize the data in modeling of carbon and methane flux.

GCRP Contact:

The point of contact is Daniel Marks, EPA-ERL-C. Chris Elvidge of ORD/DRI will coordinate this activity to provide linkages with non-NALC remote sensing programs.

Phones: Marks, 430-4634 or 503-754-4634 FAX -4799

GCRP Goals:

The goal is to estimate the extent and the change over time of rice growing lands. The information will assist the evaluation of carbon pool and flux, and the potential for generation of methane from cropped anaerobic soils. These and other data can be helpful in analysis of management activities and may potentially assist in development and implementation of policies.

The remote sensor data can supply data on the location and extent of rice lands, and multiple date analyses will yield information on change. A goal of the program is to evaluate US rice growing areas, and develop methods to supply information. Later, these techniques can be used to evaluate other rice growing lands. It is also a goal of the Landsat Pathfinder program is to develop a Multispectral Scanner (MSS) data set for Southeast Asia. The format will be similar to that of the North American Landscape Characterization (NALC) program. From this effort, it will be possible to estimate the rice lands of Southeast Asia and provide tabular and imagery summarizes of the data.

NALC Applications (Standard Products):

The standard products that apply to this work element would be land cover/land use images and tabular data, and evaluations of change. Unprocessed data and standard image products may also be useful.

NALC Applications (Modified Products):

NALC data products and analyses will provide assistance with characterizing and quantifying certain variables. These may include optimization of images for detection of change in extent of rice land and change in management. Analysis of change induced by fire, pestilence, and weather is necessary, and the management practices subsequent to the event would be of interest.

Scheduling for Deliveries of Standard Products:

Current NALC scheduling calls for the above products to be delivered in calendar years 1996 for the Western US such as rice growing areas of California. In 1997 the midwest and Great Plains and Eastern-Southern US will be available, and supply detail on rice growing areas in Louisiana, Arkansas and other states.

Potential Schedule for Modified NALC Products:

The above issues may be addressed in preliminary tests of the NALC program. The levels of sensitivity can be evaluated, and suggested modified products could be generated the data production work by Cooperators in support of GCRP. The timeframe would be the same from the standard products.

Proposed Coordination Action/Schedule:

Much of this effort will involve production of data sets and standard and modified products by Cooperators. Hence, it would be desirable to collaborate on Cooperator contracting issues to insure that the products of interest are addressed early in the delivery timeframes, and that modified products of interest to GCRP researchers will be generated.

Appendix VIII:

NALC Product Refinement Workshop

- Agenda
- Participants
- Workshop Summary
- Letter Reports
  - Houghton
  - Lawrence
  - Salas

NORTH AMERICAN LANDSCAPE CHARACTERIZATION (NALC) - PATHFINDER

PRODUCT REFINEMENT WORKSHOP
April 27, 1993
Las Vegas, NV

8:00 AM	WELCOME Eugene Meier - U.S. EPA, EMSL-LV
8:15 AM	INTRODUCTION & NALC OVERVIEW PRESENTATION Ross Lunetta - NALC Technical Director
9:00 AM	U.S. EPA GCRP Land Cover Data Requirements Peter Beedlow - ERL/Corvallis Perspective
9:30 AM	U.S. EPA GCRP Land Cover Data Requirements Lee Mulkey - ERL/Athens Perspective
10:00 -10:20 AM	BREAK
10:20 AM	Tropical Deforestation - Data Base Products William Lawrence - University of Maryland William Salas - University of New Hampshire
11:00 AM	Carbon Modeling - Model Input Requirements Richard Houghton - Woods Hole Research Center
11:40 AM - 1:00 PM	LUNCH
1:00 - 1:30 PM	EMSL-LV Remote Sensing Laboratory Tour

DISCUSSION SESSIONS

1:40 PM	NALC MSS LAND COVER PRODUCTS
2:50 PM	NALC MSS LAND COVER CHANGE PRODUCTS
4:00 PM	NALC DATA QUALITY OBJECTIVES
5:00 PM	PARTICIPANTS CLOSING REMARKS
5:30 PM	ADJOURN

NORTH AMERICAN LANDSCAPE CHARACTERIZATION (NALC) - PATHFINDER

PRODUCT REFINEMENT WORKSHOP
April 27, 1993
Las Vegas, NV

Workshop Participants:

Name	Affiliation
Peter Beedlow	EPA/ERC-Covallis
Richard Houghton	Woods Hole Research Center
William Keith	EPA/OMMSQA-HQ
William Lawrence	University of Maryland
Barbara Levinson	EPA/OEPER-HQ
Ross Lunetta	EPA/EMSL-Las Vegas
John Lyon	OSU/EMSL-Las Vegas
Gene Meier	EPA/EMSL-Las Vegas
Lee Mulkey	EPA/ERL-Athens
William Salas	University of New Hampshire
James Sturdevant	USGS/EROS Data Center
Hal Walker	EPA/ERL-Narragansett
Dorsey Worthy	EPA/EMSL-Las Vegas

GLOBAL CHANGE SCIENCE ISSUES
NALC PRODUCT REFINEMENT WORKSHOP

Las Vegas, NV, April 27, 1993

WORKSHOP SUMMARY

The workshop was organized to address several questions advanced by the Technical Review Panel. These questions focused on the use of the NALC data products by the science community.

One question was how to optimize the match between science issues and the products that NALC will supply in support of these Global Change Research Program issues. A second question or effort was how to define products better with help from Agency and other global change scientists, and thereby to further optimize the products for science applications.

The major Agency science clients and other global change scientists presented their research program related to global climate change, and identified how NALC products will assist these efforts. The global change scientists have provided their response to the project and this information is provided here.

Laboratory Science Issues

The Environmental Research Laboratory (ERL) in Corvallis is concerned with several programs related with global climate change. In particular, the assessment of forest management practices envisions the use of NALC products. The goal is to identify strategies for the sequestration of carbon in forest land cover through improved forest management practices. The initial area of activity is in southern Mexico, with later work in Brazil and perhaps the Caribbean. The plan is that NALC will provide a land cover baseline and the land cover change over the last twenty years.

An additional area of effort is the forest sector carbon budget. This is focused on the western and eastern US, Mexico, Brazil and the former Soviet Union. In the US and in the former Soviet Union good forestry statistics are available for estimation purposes. In Mexico and in Brazil these statistics are rare, and in Mexico it is hoped that NALC will help provide the spatial distribution of land cover types for forest carbon budget estimates.

A third area of interest is the program of modeling the global redistribution of vegetation due to climate change. These process models require baseline information on the distribution of vegetation and NALC data can potentially be used to initiate the modeling scenarios. NALC data may also be useful for verification or validation of the results of climate and vegetation distribution scenarios.

In general, NALC data can be useful to predict the spatial distribution of vegetation or plant assemblages. In these efforts, NALC data along with known variances or uncertainties can be used with carbon density estimates for each land cover type of interest. The combination of spatial distribution of land cover from NALC and carbon density of land cover types from field experiments, along with uncertainties of each estimates, will help allow a determination of spatial distribution of carbon and a carbon inventory. Use of NALC land cover change data along with carbon density data will potentially allow estimates of carbon flux over the last twenty years.

The Environmental Research Laboratory in Athens suggested several areas where NALC data may be useful. NALC land cover data may be useful in their efforts to model the release and sequestration of carbon and other atmospheric trace gases in soils (methane, nitrogen compounds). Land cover could be important in determining the spatial distribution of managed land cover types and their soils, and help fix these quantities for use as input to models.

A second area of effort would be in their determinations of greenhouse gas budgets (GHG) and how they are influenced by land use changes and the land use management activities. In this case, the change of land cover types as determined from NALC products could be useful in better estimating the area that these processes occur.

The Agency and other global change scientists discussed the general value of Multispectral Scanner Data (MSS). It is clear that MSS data are valuable as compared to coarser resolution data, as based on spatial resolution, spectral resolution, and the twenty-year digital data archive. In particular, the estimates of deforestation in Mexico and Central America are a valuable use of MSS and NALC data products, due to the lack of organized forestry statistics.

A number of visiting global change researchers discussed their work and addressed the potential contributions of NALC products to science issues. Their inputs are included throughout this document. In particular, they agreed upon the potential value of NALC products. NALC products can be used as a baseline and serve a valuable role as there are no data sets available for these researchers to use. It will also supply data with known accuracy characteristics, and this is valuable for making better quality estimates of carbon stocks.

Comments on specific elements of the NALC technical plan and the data products are presented below.

Land Cover Products

Land cover category products will be valuable for carbon inventory and flux calculations. The NALC products will supply the general land cover types. Carbon density estimates for each land cover type can be developed from field data. Carbon density data and NALC products on land cover can be used to integrate or inventory carbon stocks. Land cover types will provide the mechanism to distribute the carbon and calculate stocks.

A further advantage is the definition of the current condition or current boundaries. This definition of baseline is important for monitoring change, for setting initial model conditions and verifying model results.

In terms of land cover, it is desirable to determine the antecedent forest types, the timing of the event such as forest harvesting or a forest fire, and the current condition such as whether the site was reforested.

From a regional forest carbon budget viewpoint, it would be desirable to use the NALC land cover woody class to compare forest source/sink conditions in the US. For example, it may be desirable to examine the carbon sink conditions in the eastern deciduous forest and in the southeastern forests, as compared to the carbon source conditions in the Pacific Northwest.

A number of scientists were supportive of the availability of "raw" or slightly processed data sets as they come from the EROS Data Center (EDC). This may be a very useful product and may be favored by certain application scientists.

The land cover categorization scheme was deemed adequate to address the needs of carbon cycling researchers. It was emphasized that the land cover categorization scheme was optimized for identification from the MSS instrument.

Land Cover Change Products

Two techniques will be used for production of change detection products. These include images generated from the brightness value data through differencing of multiple band data (pre-categorization). The second approach will employ comparisons of categorized and labeled scenes or a post-categorization effort.

The two techniques are to be proposed due to some of the great differences found in different image scenes. The first technique is the easiest to implement and will be used in a number of locations. The second technique will be useful where there is a high level of cloud cover, or a great difference in seasonal dates to be compared.

One valuable result of MSS-based NALC data is the identification of both carbon sinks (afforestation for example) as well as carbon sources (deforestation). NALC will be able to identify both and provide quantities and spatial distribution.

Global Change Research Program Pilot

It is necessary to develop further the utility of NALC and related products in Agency global change research experiments. To develop the NALC products and their applications to science issues there will be Process Pilot studies. These studies will link the NALC and related products to field and lab based measurements, and allow use of results in modeling activities.

The Process Pilot studies will examine measurements of soil carbon and soil moisture with field and sensor instruments, and will seek to identify forest or woody land cover type using combinations of sensors such as NALC MSS and satellite and airborne radars. The evaluation of radar data would be performed under EPA'S core remote sensing research program as it is beyond the current scope of the NALC project.

Data Quality Objectives

It was deemed important to conduct an accuracy assessment of the land cover categories. The uncertainties of estimates in land cover, or for that matter in process estimates, are important to supplying error bounds on calculations that use NALC results. The accuracy assessments of individual categories are vital in carbon flux calculations. Large variations in uncertainties will greatly weaken estimates and broaden those estimates to the point of diminishing value. Hence, it is important to assign accuracies or uncertainties to address carbon science issues.

The data quality objectives as presented at the Workshop were deemed adequate for the proposed uses of the data.

Various science users may require more detail than is available from the land cover categorization system and the level of accuracy supplied by NALC. Hopefully, needs that go beyond the requirements of the NALC project can be met with additional processing of the pre-categorized or categorized NALC data sets.

A Report to the NALC Overview Committee
following the April 27th, 1993 workshop in Las Vegas, NV

R.A. Houghton
April 29, 1993

THE IMPORTANCE OF NALC PRODUCTS TO SCIENTIFIC ISSUES

As part of the Landsat Pathfinder program, the North American Landscape Characterization (NALC) Project helps prepare the EOS community for handling large volumes of data, searches the current Landsat archive, accumulates additional current scenes, and makes products available and useful to the broader user community.

More specifically, the NALC Program will provide information useful for analysis of the global carbon cycle. In particular, it has the potential to offer three products that are essential for carbon cycle research:

1. Triplicate (1973, 1986, 1991) Landsat scenes for all of North and Central America, including the Caribbean (coverage of Canada will be provided independently by the Canadian Center for Remote Sensing). For the approximately 20-year record of Landsat, these triplicate products will provide estimates of change in forest area. Change in the area of forests is currently the single most important datum for determining the flux of carbon from land use. (As satellite data are used to provide these data globally over the next years, variation in carbon density (biomass and soil carbon) will become the factor contributing most uncertainty to estimates of terrestrial carbon flux. Rate of change in forest area is most important at present, however.)

2. Images of change between the three dates over the 1972-1991 period. Change in the area of forests is most important and is readily determined from Landsat MSS. Carbon density is not. However, carbon density may be determined indirectly from Landsat data if change detection is carried out with pre-classified data. For example, change detection may be able to identify logging and regrowth if young and old forests are not first classified as identical. And there may be other changes and variations observable with Landsat MSS data that could serve to determine carbon densities indirectly (see Level of Classification, below). Every effort should be made to include not only changes in forest - nonforest, but changes in the age, structure, and condition of ecosystems.

3. A base map (1991) for North and Central America against which to compare future land covers. The value of such a digital product can be appreciated by considering how much more we would know <u>now</u> about sources and sinks of terrestrial carbon if we had such images of land cover, globally, over the last 100 years. (AVHRR would provide such images for less money, but not with a resolution that allows

monitoring of deforestation/reforestation) (see below).

Potential uses of the NALC products (base map and 20-year record of changes) include:

A. Determination of net flux of carbon from changes in land cover (Note: The net flux of carbon in 1990 is dependent on regrowth of forests logged before the launch of Landsat. Such forests are currently accumulating carbon, contributing to a carbon sink. For this reason, sinks are difficult to document with only 20 years of satellite data. The 20-year record of Landsat will overestimate terrestrial emissions because releases of carbon from logging are greater per unit area than long-term sinks of carbon associated with regrowth. Over the period of Landsat, deforestation will have released some amount of carbon. But regrowth of forests on lands harvested or abandoned before 1972 will be accumulating carbon and will not be 'seen' by Landsat. This bias must be considered by those who would use the NALC products to determine flux.

B. Determination of the areal extent of major land cover types. A knowledge of land cover will, in turn, be useful for:

a. assigning carbon densities (biomass and soil carbon) for determination of North American carbon stocks. (Note: assigning carbon densities is required for A, above, for at least that part of the region that shows change);

b. estimating the potential for carbon sequestration. Again, carbon stocks for each cover type will have to be assigned independently of the NALC products. NALC will provide the detailed digital product (the map);

c. assigning greenhouse gas fluxes of CH_4, N_2O, CO to cover types;

d. assigning climatological parameters (e.g., albedo, roughness, rooting depth, etc.) to cover types.

e. other?

C. The NALC 1991 base map will be useful in the future to determine areas that indicate change, either as a result of

a. land-use change, or

b. climate change.

Monitoring programs such as NALC must be continued in the future. Ten-year intervals may be adequate in temperate and boreal regions; five-year intervals or less may be required in the tropics.

Why North America?

The contribution of North America to the global terrestrial flux of carbon is thought to be small. Furthermore, the net flux cannot be determined with data provided by NALC alone (independent data on historical land use and on carbon densities are required). Nevertheless, the flux from North America is important because the global flux is the sum of all regions. If we consider only the regions of large source strength, we will have only part of the flux --- most of it, perhaps, but only part. Accuracies in global estimates are now $\pm$0.5 PgC or better (combustion of fossil fuels releases 6 PgC/yr $\pm$ 10% (15%)?). Furthermore, we probably don't know areas of flux well enough to be certain of identifying the "important" regions. All regions are important, or have the potential to be so in the future. We certainly do not know the regions where a major carbon sink exists. My suspicion is that we don't know well even the land-use flux from temperate and boreal regions. What is the role of fire, for example? Has the frequency of forest fires increased? Will it in the future?

We need to know the flux of carbon from land-use change (including both sources from deforestation and sinks from regrowth), globally. The need results from the fact that there are two components to the terrestrial flux of carbon: a component related to changes in land use (direct human effects), and a component related to other, more subtle effects (climatic change, elevated CO_2, increased availability of fixed nitrogen or other nutrients or toxins). Changes in these environmental factors affect metabolism and, hence, the storage of carbon per unit area. Such changes are very difficult to appraise locally, let alone globally. So far, only the component resulting from direct human effects can be determined; the other component has never been measured. It has been inferred indirectly from analyses based on geophysical data --- in other words, by difference. The land-use component (the first one) is important to determine accurately because it helps constrain the magnitude of the second component. One should measure what can be measured.

Sources are important even in a region that is thought to be largely a sink. Together the sources and sinks provide the net flux, and the net flux is required for the global carbon budget. (Bank accounts are not balanced by considering only deposits.)

We need to know the flux associated with global changes in land use to $\pm$0.5 PgC or better (0.2 PgC?) in order to reduce the uncertainty to a level consistent with other terms in the global carbon equation (atmosphere, fossil fuels, oceans). Thus, despite the fact that North and Central America may not be regions of high flux at present, their contribution to atmospheric carbon must nevertheless be determined. The determination need not require wall-to-wall coverage with triplicates of Landsat MSS. For determination of land use change over the last 20 years, wall-to-wall inventories or wall-to-wall application of change detection might be applied only to hot spots, with some intensity of sampling used to cover areas not thought to be undergoing change. But while sampling may be adequate for retrospective estimates of land-use change, it will not provide a baseline map. A map with usefulness for the future will require wall-to-wall coverage, and I think establishment of such a map is highly justified (see Landsat MSS vs AVHRR, below).

Level of Classification Required

If the NALC products are to be used to calculate carbon emissions from land-use change, a level 1 classification is adequate. Forest - nonforest is the change involving the greatest change in carbon. Types of forest are generally less important.

If the NALC products are to provide a baseline or inventory of cover types for subsequent assessment of change or subsequent assigning of biomass, then the highest level of classification possible should be used. However, even the highest levels of classification (at great expense) would probably be inadequate. What is needed for carbon cycling is a combination of sensors that will give biomass (and soil carbon). The techniques are not yet developed, but when or if they are, my guess is that existing land-cover classifications will not be adequate for assigning variations in carbon stocks. New classification will be required, based on the new sensors of biomass.

The state of the art classification of 85% accuracy 75% of the time suggests that pre-classification change detection is better than post-classification, especially if level 1 classification is used. For example, level 1 recognizes woody vegetation, which would include in the same class both old growth forest and young forests. Post-classification change detection would show no change after 5-10 years of regrowth following logging. Pre-classification change detection, on the other hand, would show a change --- and the change is important. It allows aging of the forest and indirect estimation of structure or biomass.

Pre-classification change detection should be used as an exploratory tool in all regions, and should be explored in the pilot studies of NALC. Level 1 is probably appropriate for classification <u>but</u> pre-classification change detection should be used to determine the level of classification appropriate for cover types that have changed.

Landsat MSS vs. AVHRR

AVHRR is cheaper.

AVHRR has high temporal resolution (twice daily).

AVHRR is good for broad categories.

Landsat has high spatial resolution.

Landsat is good for land-use change. AVHRR overestimates deforestation. (Could MSS be used to determine a correction for AVHRR? Early studies suggest not; in areas where forest cover is <70%, AVHRR may either over- or under-estimate it.) Landsat MSS or TM is near the lower limit of resolution for determining short-term changes in forest area.

Implications

In a strict sense, there are at least two scientific issues here, and they might be most economically addressed with different approaches. First, for determination of the net flux of carbon between North American ecosystems and the atmosphere, one needs high resolution Landsat data, but not necessarily wall-to-wall. Stratified sampling would probably be adequate and would be more economical. On the other hand, for establishment of a baseline map, LAC AVHRR might be adequate and might be more economical than Landsat (significantly more?). The NALC program is in a position to address both issues (20-year change and base map). It is not clear from these two issues, alone, whether NALC should attempt to address both. There may be other uses of the products that help determine the appropriate goals for NALC. If the net flux of carbon is important not only over the last 20 years, but over the next decades, as well, then a good argument exists for obtaining, now, wall-to-wall coverage with Landsat MSS.

Letter Report on NALC Pathfinder
Product Refinement Workshop
US EPA EMSL-LV April 27. 1993

submitted by:

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Summary:

My immediate impression of the NALC Pathfinder Project is that it is perceived within EPA as a very carefully designed data product with an as yet poorly defined science product and end-user community. The fault in the product's definition seems more conceptual than actual. I find the project very much on-track.

It is clear to me that the proposed products of NALC will prove to be extremely valuable to the science community. The mapped, cloud-screened MSS image triplicates are in themselves an invaluable product. The addition of a straightforward change classification and lineage attributes make the basic dataset even more useful. This community-wide value will become apparent once the product stream is robust enough to allow general announcement and release of the products to the ex-EPA user community. At present, it seems that there is still a strong outreach effort to be undertaken within EPA to generate some excitement about the NALC product and its wide application. The dual roles of this project; fulfilling both NASA Pathfinder and EPA Lab-wide needs makes it much more difficult to build a strong consensus. However, the initial interactions I observed between NALC, Athens and Corvallis labs seems to be the very promising beginning of collaboration that will be of benefit to all involved.

Products/End Uses:

There is a high level of interest in generating products beyond the triplicates and associated land cover/land cover change maps within NALC Pathfinder. Such an effort on the part of NALC would be an over-commitment of both time and resources, and is best left for later collaborative, user community or EMSL-LV led efforts that will surely follow given the tremendous potential applications of the basic data product. I think it became clear during the Product Refinement Meeting that, given appropriate examples and some in-depth familiarization, projects at both Athens and Corvallis labs could make very profitable use of the basic suite of NALC data.

Some of the immediate uses of this basic dataset were made very apparent during the presentations and discussions. I have outlined a few below.

Soil carbon contents - The brief discussion of work at the

Athens lab brought many potential uses of NALC data to mind. The large scale soil carbon modeling of this group could benefit greatly from the utilization of a spatial dataset such as NALC. This is not a trivial application, but a project that would require some time to carry out. However, the results would not only test the linkage of statistical and spatial data, but also help define the accuracy of the current methodologies with their broad spatial generalization.

Global Carbon Stocks - Both Athens and Corvallis labs are interested in global carbon stocks. The standard approach uses non-spatially explicit values for models. The use of spatial data, such as the NALC product, for distribution of carbon densities across landscapes present very real difficulties, so have not been widely used. This is an area of research that could profitably engage both NALC and other EPA labs in development of state-of-the-art science products. Other closely related modeling efforts that could use the NALC products are the whole suite of Earth-system modeling projects, assessment of management practices on carbon cycling, greenhouse gas emission, and global carbon balance studies.

State-of-the-Art Maps - The NALC land cover products will be the first ever available for accurate assessment of the spatial extent and change in important land use types. No such baseline maps exist at the scale of the NALC. Simple spatial analyses of the land cover maps can yield statistics on the state of cultivated lands, deforestation, and even wetland distribution. Such maps are critical to accurate parameterization of ecosystem models and assessment of management planning. Applications in social and political science, and other as yet unidentified fields are sure to follow the wide distribution of this dataset.

Methods:

Digital Triplicates - The digital triplicates seem extremely well thought out in terms of the content, mapping, and cloud-reduction mosaic processing. I am a bit concerned that the types of distribution files are proliferating as changes are made in the data stream, ie. the method of copying mosaics. If a data layer is made for each of several cloud contaminated images, rather than the earlier mosaic process, things begin to get very complicated. A simplification might be the distribution of two cloud cover exclusive scenes for any one year without masking or mosaicing. These datasets may get so voluminous that they are impossible to distribute once classification, lineage, land cover and land cover change layers are added. Distribution of a very basic land cover and land cover change dataset would be useful. Many users need only the product, not the entire digital dataset. Additional information might include 8-bit color composites for each year simulating visible or near-IR photoproducts.

Unsupervised Classification - Care should be taken not to distribute too many classes. Tens of classes from an initial classification should be sufficient to describe the basic variability for the collaborators that are doing the labeling and aggregation. I understand that this process is still in development. Some image smoothing may also be useful. We find that our digital classification produces a data product that is entirely too complicated, so majority filter smoothing and removal of groups of pixels below a minimum mapping unit is used to simplify the basic data prior to editing and analysis.

The type of change detection to be used need very careful attention. Whether to use pre- or post-classification detection will probably depend on the types of change and land cover present, as well as your ability to normalize MSS scenes through time. If normalization is successful, then I would suggest the distribution of the normalized images, rather than the raw products.

Classification of Land Cover Types - There was some discussion of the level at which to distribute the land cover information. I would let your collaborators classify to the finest detail that they can, using digital and ancillary datasets, with later post-processing to aggregate the data to the lowest common denominator, which would be based on your classification criteria. In any case < level 2 [Ecologically-oriented Land Cover Classification System] would be unacceptable for most ecological or Earth-science modeling uses, especially when concerned with carbon modeling. The finer classifications, when successful, could be distributed as case studies, or even as separate data layers. A useful paradigm might be distribution of the MSS digital triplicates *separately* from the land cover and land cover change information.

Results of Meeting:

The Product Refinement meeting was valuable for me and hopefully our outside point of view will prove useful to the EPA NALC Project as well. During the meeting I learned much of the NALC and its placement within EPA and among other EPA laboratories. The basic triplicate product of NALC is of exceptional value, as it makes a uniform set of image products available to EPA and other researchers. The near-term science product, the land cover characterization and change maps, will prove to be even more important to the user community, but clearly are still in a developmental stage. Much intensive research remains before a truly operational land cover and/or change product is forthcoming, but this should be accomplished in the near-term. The research planned for the Chiapas and Oregon Transect pilot studies will probably meet these developmental needs and answer many methodological questions that remain. A very fruitful collaboration with Athens and Corvallis labs in terms of NALC dataset development and utilization seems highly likely. These collaborations will not only enhance the NALC process but also serve to further the linkage of spatial and statistical datasets in modeling.

Recommendations -

- use pilot studies to test utility of unsupervised classification and appropriate level of detail for land cover class identification
- a pilot study in agriculturally-dominated landscapes may be useful to test land cover classification methodologies [if such land cover types are not well represented in current pilot study sites]
- go into production mode with basic products - triplicates, land cover change - let later projects develop the more discipline-specific science products
- build constituency with other EPA labs, using them to help define future products/collaborative research efforts - this will be somewhat of an NALC 'outreach' until others catch on to the utility of this multi-temporal dataset
- formalize inter-lab NALC data based research in some way - eg. travel funds, some limited support
- consider wide distribution of a simple dataset, eg. land cover classes for three periods, plus change and perhaps an 8-bit color composite [visible or near-IR - no MSS digital} as this will reduce the data volume and suit many applications
- MSS digital triplicates might be distributed separately from all land cover/land cover change data, if datasets become unmanageably large
- 'radiometric rectification' or some normalization of the digital data may be useful prior to distribution - research work on pre-classification change detection will clearly show if this is a viable option
- maintain close ties with other Landsat Pathfinder projects, especially in change detection methodologies - NALC land cover classification could be applied to other Pathfinder datasets

William T. Lawrence
May 10, 1993

North American Landscape Characterization (NALC)
Product Refinement Workshop
EMSL-LV April 27, 1993

Review comments by William Salas.

A product refinement workshop for the North American Landscape Characterization project (NALC) was held at the Environmental Monitoring Systems Laboratory in Las Vegas on April 27, 1993. This workshop was extremely informative and useful.

As part of the Landsat Pathfinder program, NALC is making important contributions in data processing, distribution, and archiving techniques needed for development of EOS-DIS. In particular, the use of EDC as the Land DAAC to create triplicate MSS images that are image to image registered demonstrates how a "science computing facility" could use a DAAC in the EOS era. While this point may seem trivial, it is an important test of the DAAC-SCF infrastructure design of EOS-DIS. NALC's assistance in completing the MSS 1992 acquisition for complete coverage of North America is another important contribution in itself. The now complete 20 year archive of MSS data is an extremely important data set, in that it provides the capability to study temporal phenomena over a 20 year period with the same instrument.

The processing algorithms being developed by NALC for land cover and land cover change mapping are important but difficult tasks. Characterization of thematic classes for large areas over time is extremely difficult using remote sensing data, and as a result has not been attempted until the recent implementation of the Landsat Pathfinder projects. Success of these programs will demonstrate the ability to handle massive, multitemporal, high spatial resolution data sets. However, in order to succeed efficient processing algorithms are needed. NALC use of pilot studies to assess the utility of several candidate processing algorithms is imperative since the success of the algorithms may depend on the regional under study. NALC pre-classification change detection strategy is exciting and should provide a better product for the science community.

Overall the NALC project has a solid start toward obtaining their goals of producing "land cover and land cover change data products at sub-kilometer spatial resolution" for most of North America and the project will be a success. However, as with any project, there are a few areas of concern that if addressed could possibly enhance the success of the project.

The project needs to address how the NALC products may be used throughout the science community, not just within the EPA. I realize one of the goals of this meeting was to address this issue, but, for example, there are many EOS investigators that would be extremely interested in hearing about the NALC project and could integrate the NALC products with ongoing EOS research.

For instance, there is a group at the University of New Hampshire that would be extremely interested in providing inputs to NALC regarding the land cover data sets for the northeast US and how the data could be used to supplement their efforts to model net primary production and evapotranspiration in the region. As another example, NALC data products could be used as test sites for the North American AVHRR 1-km project. This is an important exercise in how can high spatial resolution be scaled up for use in testing the lower. As a result I suggest that another pilot project be developed to directly link the NALC data set with an existing global change research project. This would enhance the visibility and broaden the base of support for NALC, as well as demonstrate how the data products can be used to address specific global change research needs.

The use of a clustering algorithm for an entire scene may present some problems. From experience we have scene that variations in atmospheric conditions within a scene can cause different land cover types to have the same spectral characteristics. This occurred often occurred in scenes along or near coastal areas, due to differences in the atmosphere over terrestrial and marine areas. As a result, the scene needed to be broken up into smaller areas to accurately classify land cover types.

The data analysis tracking techniques are an important part of a large processing oriented project like NALC and the current system of creating a bitmap relating the origin of each pixel is important and properly addressed. However, some thought as to how to account and track sidelap (7% at equator to 60+% in Alaska) in the processing stream is needed.

Verification procedures and accuracy assessments are difficult to provide for large projects like NALC. The procedures for spatial sampling outlined during the workshop and in the technical work plan are good. A measure of variability in labeling due to differences in individual interpretation should be addressed.

The concerns provided here are minor and an emphasis on all the good aspects of the project should be inferred. The project has a strong understanding of its goals and has presented a well thought out and realizable approach to insure that the goals are met. It was extremely instructive for me to sit in on this workshop and I hope my brief comments can be of use to the project.

Appendix IX:

Landsat Pathfinder Initiative and the Canada Centre for Remote Sensing (CCRS), and Documents from the December, 1992 Meeting with CCRS.

Landsat Pathfinder Meeting

December 9 & 10, 1992

T. Fisher

EPA/EDC/CCRS Meeting
December 9 & 10, 1992

Agenda

December 9, 1992 in Room 301 - 09:00 - 12:00

• Introduction	Terry Fisher
• Welcome to CCRS	Florian Guertin
• Review Agenda	Terry Fisher
• Pathfinder Overview	Ross Lunetta
• North American Land Characterization (NALC)	Ross Lunetta
• NALC Data Processing Overview	James Sturdevant
• NALC Standard Data Processing Methods	John Lyon
• Discussion	

December 9, 1992 in Room 201 - 13:00 - 16:00

- Detailed discussion on pathfinder processing methods and algorithms
    - catalog querying
    - radiometric processing
    - geometric prcessing
    - product definition & distribution

December 10, 1992 in Room 201 - 09:00 - 15:00

This day will be devoted to discussion of topics of mutual interest including: CCRS Global Change initiatives, change detection, etc. and possibly a tour of CCRS facilities at Booth Street.

Suggested areas:

- CREO Optical tape
- GEOSCOPE
- ERS-1 Mosaics / system
- GCNet/Video Disk

LANDSAT PATHFINDER INITIATIVES
AT THE
CANADA CENTRE FOR REMOTE SENSING

In February 1993 a project was initiated at the Canada Centre for Remote Sensing (CCRS) to develop and demonstrate capabilities to manipulate and post-process LANDSAT Pathfinder data. Of particular interest is the ability to merge scene-based imagery into seamless mosaics for large area monitoring purposes. The project, which will be completed at the end of March, 1995, will include the development of a PC-based, prototype workstation. As a means to demonstrate this technology and to increase Canadian scientific community awareness of the potential of Pathfinder imagery, an example mosaic of the Great Lakes region will be generated for the 1986 time window. The mosaic will include both U.S. Pathfinder products and Canadian coverage pre-processed on Canadian systems. The prototype workstation will expand upon a current capability for spaceborne SAR image mosaicking and will include (a) radiometric and geometric normalization, (b) automated seam delineation, (c) selectable spatial resolution and (d) a simple DBMS to aid in planning processing strategies and in monitoring and assessing processing status and product quality.

The present U.S. program does not include plans for the routine inclusion of Canadian coverage. As an added objective, CCRS will conduct a technical assessment of Canadian operational products with a view to their potential as a source of Pathfinder data.

PRODUCTS

- LANDSAT MSS
  - GEOREFERENCED FULL SCENE
  - GEOCODED
- LANDSAT TM
  - GEOREFERENCED FULL SCENE AND QUADRANT
  - GEOCODED

DIRECTORY AND INVENTORY SERVICES

- SELECTION OF SCENES BASED ON ANY LOGICAL COMBINATION OF THE FOLLOWING FIELDS:
  - SATELLITE ID
  - SENSOR ID
  - SENSOR MODE (IF APPLICABLE)
  - VIEW ANGLE (IF APPLICABLE)
  - ACQUISITION DATE
  - ACQUISITION TIME OF EACH SCENE
  - IMAGE QUALITY
  - CLOUD COVER
  - GEOGRAPHIC COORDINATES

- CROSS INVENTORY SEARCHES
  - SEARCH ANY OR ALL SATELLITE/SENSOR DATABASES FROM A SINGLE USER REQUEST

QUICKLOOK PROCESSING AND ARCHIVING

CCRS SATELLITE ARCHIVE (AS OF DECEMBER 31, 1990)

Mission	Start Date	Total Scenes Received	Useable Scenes
Landsat MSS	Jul 1972	387,157	72,767
Landsat TM	Aug 1982	106,505	18,473
SPOT (Multispectral)	Apr 1986	135,420	24,909
SPOT (Panchromatic)	Apr 1986	315,718	43,015
MOS-1 MESSR	May 1988	31,374	4,953
TOTAL		976,174	164,117

March 19, 1991

DIRECTORY AND INVENTORY SERVICES

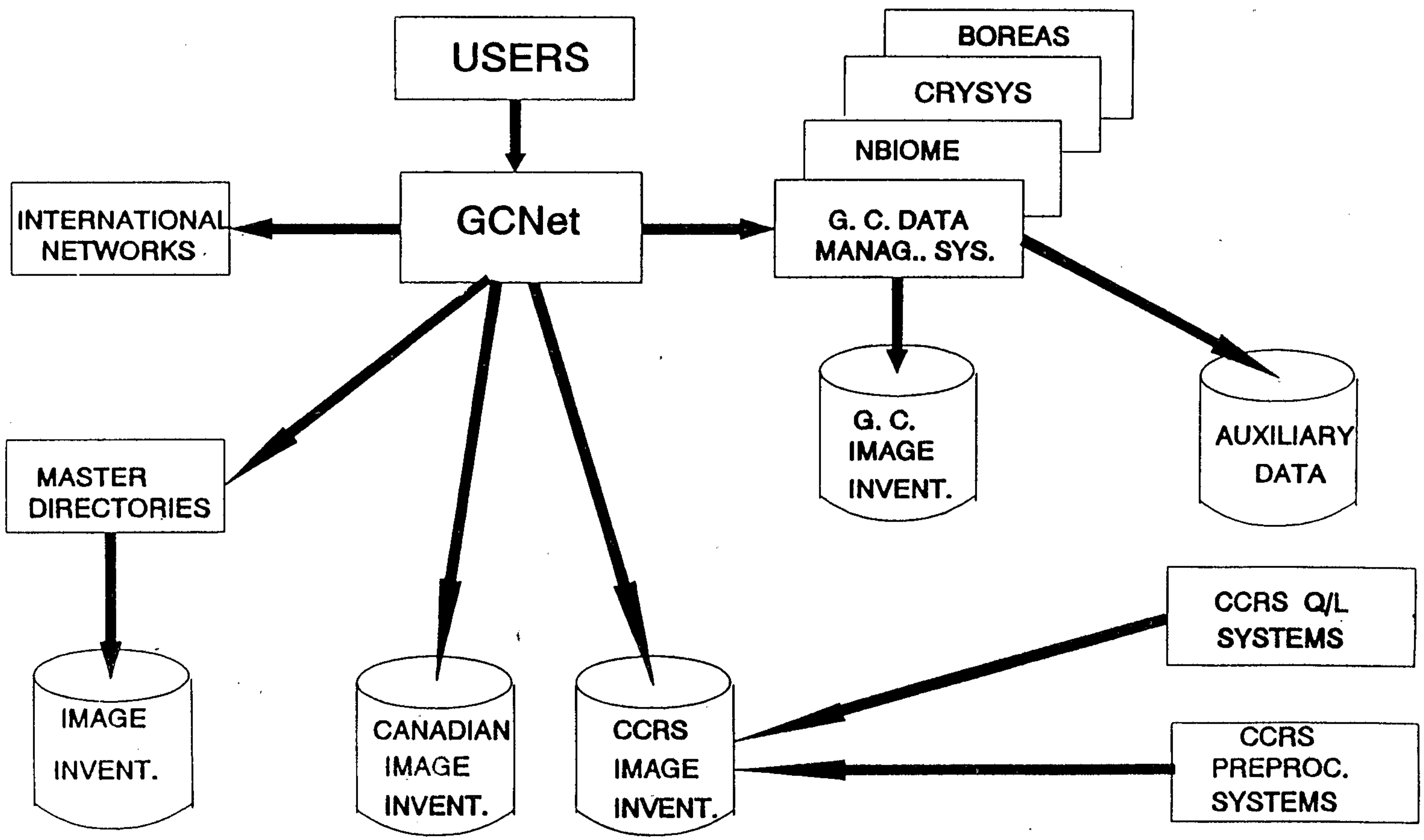
GCNET DIRECTORY SERVICES

- DIRECTORY SEARCH FOR DATA SETS OF INTEREST BY A VARIETY OF CRITERIA, SUCH AS PARAMETER KEYWORDS, GEOGRAPHIC LOCATION AND TIME;
- WHEN A DATA SET OF INTEREST HAS BEEN IDENTIFIED THE USER CAN AUTOMATICALLY CONNECT TO DIRECTORIES AND TO CATALOG SYSTEMS;
- IT PROVIDES A SINGLE POINT OF CONTACT FOR CANADIAN GLOBAL CHANGE PROJECTS SCIENTISTS AND FOR OTHER USERS WHO WANT TO OBTAIN INFORMATION ABOUT CCRS' AND OTHER CANADIAN DATA HOLDINGS;
- DIRECTORY FUNCTIONS ARE BASED ON THE NASA MASTER DIRECTORY STANDARDS.

DIRECTORY AND INVENTORY SERVICES

- OUTPUTS
  - TABULAR REPORTS CONTAINING INFORMATION ABOUT THE SCENES SELECTED
  - DISPLAY OF LOCATION OF SELECTED SCENES ON A REFERENCE MAP
  - DISPLAY OF BROWSE IMAGERY FOR SELECTED SCENES
  - DIGITAL FILES
  - OUTPUT OF A QUERY CAN BE DIRECTED TO A DIGITAL FILE CONTAINING DATA BASE INFORMATION FOR SELECTED SCENES

DIRECTORY AND INVENTORY SERVICES



March 19, 1991

APPENDIX X

LAND COVER CATEGORIZATION SYSTEM FOR USE IN THE NALC-PATHFINDER PROJECT

INTRODUCTION

The United States Environmental Protection Agency's (USEPA's) North American Landscape Characterization (NALC) Pathfinder program requires a categorization system that can be used to categorize Landsat MSS data across the entire North American continent. The two main categorization systems in use by Federal Agencies are Anderson et al. (1976): *A Land Use and Land Cover Classification System for Use with Remote Sensor Data*, and Cowardin et al. (1979): *Classification of Wetlands and Deep Water Habitats of the United States*.

The NALC categorization system combines features from the Anderson et al., Cowardin et al., and other systems. It provides the capability to "crosswalk" between the NALC system and other systems. Crosswalk is a categorization term referring to the ability to integrate data which has been categorized with one system with data that has been categorized using a different system. The NALC categorization scheme is a hierarchial system with broad categories at the more general levels and detailed land cover and land use categories at the finer levels. The resulting system was designed to remain relatively simple at the basic level, while still defining features most important for assessing carbon stocks and monitoring changes.

The NALC categorization system has been developed with major input from the USEPA Environmental Monitoring Systems Laboratory-Las Vegas (EMSL-LV); the NALC Technical Review Panel; and the NALC Technical Working Group. Considerable consideration was given to the interagency working group categorization activities. The Interagency Categorization System was developed through the input from many sources including the U. S. Geological Survey (USGS); the U. S. Fish and Wildlife Service - National Wetlands Inventory (USFWS-NWI); the National Oceanic and Atmospheric Administration (NOAA); the NOAA - National Marine Fisheries Service (NMFS); the University of Delaware; the Oak Ridge National Laboratory; the Salisbury State University; and the Florida Department of Natural Resources.

NALC CATEGORIZATION SYSTEM

The standard NALC categorization product for North America will be a Level II database product. However, the NALC categorization system (Table 1) currently contains three levels of information. The third level will have regional and site specific applications for global change process pilot studies and unique regional scale applications. A level is a stratum or tier of appropriate effort and technology required to derive a given level of land cover information. Each of these levels corresponds to different degrees of information processing, progressing from

NALC Pathfinder Categorization System

LEVEL 0	LEVEL I	LEVEL II	LEVEL III
Land	1.0 Barren or Developed Land	1.1 Exposed Land	
		1.2 Developed Land	
	2.0 Woody	2.1 Forest	2.1.1 Open Forest
			2.1.2 Moderate Forest
			2.1.3 Dense Forest
		2.2 Scrub/Shrub	2.2.1 Open Scrub/Shrub
			2.2.2 Moderate Scrub/Shrub
			2.2.3 Dense Scrub/Shrub
	3.0 Herbaceous	3.1 Herbaceous	3.1.1 Pasture/Grassland
			3.1.2 Row Crop
			3.1.3 Arctic Tundra
	4.0 Arid	4.1 Arid Vegetation	4.1.1 Alpine Tundra
			4.1.2 Arid Forest
			4.1.3 Arid Woodland
			4.1.4 Arid Scrubland
			4.1.5 Arid Grassland
			4.1.6 Arid Desertland
		4.2 Riparian	4.2.1 Arid Swamp Forest
			4.2.2 Arid Swampscrub
			4.2.3 Arid Marshland
			4.2.4 Arid Strandland
	5.0 Snow/Ice	5.1 Snow/Ice	5.11 Snow
			5.12 Ice/Glacier
Water	6.0 Water & Submerged Land	6.1 Ocean	
		6.2 Coastal	
		6.3 Near-Shore	
		6.4 Inland	
Other	7.0 Other	7.1 Cloud	
		7.2 Shadow	
		7.3 Missing	
		7.4 Indeterminable	

automated spectral clustering of satellite and aircraft image data, to manual collection of field measurements.

This categorization system is intended to provide a framework for categorizing a broad variety of land cover types. If more specific information is needed about a particular area, the user can modify the system by adding categories at deeper levels. Any of the Level III categories can be subdivided creating Level IV categories.

DEFINITIONS

This section contains the definitions for the categorization system. Areas are categorized and labelled according to the resources present on the ground at the time of imagery acquisition. If a agricultural field is devoid of vegetation and contains bare soil at the time of image acquisition, the field would be labelled as barren or developed rather than herbaceous.

The categorization system is divided into three organizational categories: Land Division, Water Division, and Other. The actual categories in the NALC database would be the Level I and II categories.

<u>LAND DIVISION</u>

The Land Division includes all categories other than open water and other. It is divided into five Level I categories: 1.0 Barren or Developed Land; 2.0 Woody; 3.0 Herbaceous; 4.0 Arid; and 5.0 Snow and Ice.

1.0 Barren or Developed Land

This category is composed of cleared, burned, or otherwise barren areas. This includes areas of artificial anthropogenic cover, with much of the land covered by artificial materials such as buildings and other man-made impervious surfaces. This category is subdivided into two Level II categories: 1.1 Exposed Land; and 1.2 Developed Land.

1.1 Exposed Land

The Exposed Land category includes naturally occurring areas that have limited ability to support life and other areas disturbed by man. In general, the surface of these areas are covered with soil, sand, or rocks and contains less than one-third vegetation or water. Naturally barren areas includes rock outcroppings, talus slopes, sandy beaches, etc. The exposed areas may be transitional or permanent. These areas include lands cleared for a variety of purposes, i.e., building construction, quarries, landfills, gravel pits, or strip mines. Recently clearcut forests with all the vegetation removed and bare soil agricultural fields would be included in this category.

1.2 Developed Land

This category includes areas in which 70% or more of the land surface is covered by structures and other man-made impervious features. This corresponds with those areas termed "Urban or Built-up Land" by Anderson et al. (1976) who states:

> Included in this category are cities; towns; villages; strip developments along highways; transportation, power, and communications facilities; and areas such as those occupied by mills, shopping centers, industrial and commercial complexes, and institutions that may, in some instances, be isolated from urban areas.

2.0 Woody

The category Woody refers to areas dominated by plant species that have an aerial stem which persists for more than one season, and a cambium layer for periodic growth in diameter (Harlow and Harrar, 1969). Succulents such as cacti would be included in the Arid category. The woody vegetation category requires a crown closure of 25% or greater. This category includes scrub/shrubs and trees and is subdivided into two Level II categories: 2.1 Forest; and 2.2 Scrub/Shrub.

2.1 Forest

The forest category contains single stemmed woody vegetation (trees). Harlow and Harrar (1969) defines a tree as a "woody plant which at maturity is 6 meters or more in height, with a single trunk, unbranched for at least several feet above the ground, and having a more or less definite crown". This category is subdivided into three Level III categories: 2.1.1 Open Forest; 2.1.2 Moderate Forest; and 2.1.3 Dense Forest

2.1.1 Open Forest

Corresponds to communities dominated by trees with a mean potential height usually under 15 meters a canopy which is usually open, and is singularly layered. The crown closure is between 25 and 50 percent. These areas typically have a grassland understory. Savannas are an ecotone between woody and herbaceous.

2.1.2 Moderate Forest

Corresponds to forests having a canopy closure of greater than or equal to 50%, but less than 75%.

2.1.3 Dense Forest

Corresponds to forests having a canopy closure of greater than or equal to 75%.

2.2 Scrub/Shrub

The Scrub/Shrub category contains woody vegetation which at maturity are usually less than 6 meters in height. The crown closure is greater than 25%. Scrub/Shrub are smaller than trees and unusually exhibit several erect, spreading, or prostrate stems and a general bush appearance This category is subdivided into three Level III categories: 2.2.1 Open Scrub/Shrub; 2.2.2 Moderate Scrub/Shrub; and 2.2.3 Dense Scrub/Shrub.

2.2.1 Open Scrub/Shrub

Corresponds to all Scrub/Shrub, having a canopy closure of greater or equal to 25%, but less than 50%.

2.2.2 Moderate Scrub/Shrub

Corresponds to all Scrub/Shrub, having a canopy closure of greater than 50%, but less than 75%.

2.2.3 Dense Scrub/Shrub

Corresponds to all Scrub/Shrub, having a canopy closure of greater than or equal to 75%.

3.0 Herbaceous

This category includes areas dominated by herbaceous cover. This category encompasses natural and managed areas of herbaceous cover, including lawns, natural grasslands, cultivated (agricultural) fields, pastures, or herbaceous wetlands (marshes). Land used for food production such as corn, soybeans, wheat, etc., are included in this category.

Some grasslands may have been seeded to introduce or domesticate plant species. Other grasslands are successional in an area such as areas that have been burned by fire or agricultural fields are left fallow. This category is not divided at the Level II category. Herbaceous is subdivided into three Level III categories.

3.1 Herbaceous

This category is subdivided into:

3.1.1 Pasture/Grassland

Pasture/Grassland encompasses those areas that have both managed and natural grassland cover. This category includes small grains such as oats and wheat, hayfields, pastures, lawns, herbaceous road right-of-ways, herbaceous fields, or natural prairie areas.

3.1.2 Row Crop

Row crop refers to areas cultivated for agricultural purposes. Examples include fields used to grow soybeans, corn, and potatoes. Areas that are used for agricultural purposes that are temporarily unvegetated due to cropping or tilling practices would be categorized as barren or developed land.

3.1.3 Arctic Tundra

The Arctic Tundra category exists in an environment so cold that moisture is unavailable for most of the year, precluding the establishment of trees, and in which the maximum vegetation development is of herbaceous root perennials, lichens and mosses, with grasses poorly represented or at least not dominant (Brown et al., 1979). Tundra categorized in this category consists of arctic and near arctic areas north of 60 degrees latitude.

4.0 Arid

An Arid region is characterized by dryness, variously defined as rainfall insufficient for plant life or for crops without irrigation; receives less than 25 cm of annual rainfall; or has a higher evaporation rate than precipitation rate (Dictionary of Geological Terms, 1976). In alpine settings above 5000 feet, the precipitation may be between 25 and 75 cm. The areas with higher amounts of precipitation support forest communities. Land cover types included in this category have a soil regime which is dry more than half the time when not frozen, and is never moist for more than 90 consecutive days (Buol et al., 1989). This category is divided into two Level II categories: 4.1 Arid Vegetation; and 4.2 Riparian.

4.1 Arid Vegetation

The vegetation categories within the arid represent upland communities which derive moisture primarily from available precipitation, rather than from surface water. Vegetation in these categories would often be considered the background or regional vegetation. The category is subdivided into six Level III categories: 4.1.1 Alpine Tundra; 4.1.2 Arid Forest; 4.1.3 Arid Woodland; 4.1.4 Arid Scrubland; 4.1.5 Arid Grassland; and 4.1.6 Arid Desertland.

4.1.1 Alpine Tundra

Plant communities existing in an environment so cold that moisture is unavailable during most of the year, which precludes the establishment of trees. The climax vegetation consists of herbaceous root perennials, shrubs, lichens, and mosses with grasses poorly represented. Areas categorized as 4.1.1 differ from tundras categorized as 3.1.3 by lying at high altitudes above treeline and in an alpine setting.

4.1.2 Arid Forest

Arid Forest areas are typically open forests dominated by coniferous trees over 6 meters in height. The understory may consist of grasses or other mesophytic plants, or there may be no understory vegetation. These forest areas differ from woody forested areas in that the annual precipitation is less than 75 centimeters and is an alpine setting. If found below 5000 feet the annual rainfall is less than 25 centimeters.

4.1.3 Arid Woodland

Arid Woodlands are those areas which typically contain trees under 15 meters in height which are widely spaced with singular canopies.

4.1.4 Arid Scrubland

Communities dominated by either sclerophyllic or microphyllic shrubs which generally do not exceed 6 meters in height. The canopy can be closed, or open with a perennial understory interspersed between shrubs. Areas with more than 25 percent of the ground area covered by shrubs fall into this category.

4.1.5 Arid Grasslands

Arid Grasslands include those areas in which the dominant vegetation consists of grasses and other herbaceous plants. There may be some shrubs scattered within this category but less than 25%. In some cases the differentiating factor between this category and the woodland is the spacing of the trees. Areas with more than 75 percent of the ground cover containing grass fall into this category.

4.1.6 Arid Desertland

Vegetation in this category can be either annual or perennial. The areas between plants usually consists of rock or sand with virtually no intervening vegetation.

4.2 Riparian

It is understood that riparian communities exist within all types of landscapes. These communities are wetlands associated with a stream, or river. The defining factor in this category is that the average annual precipitation is less than 25 centimeters. Four Level III categories lie within this category: 4.2.1 Arid Swamp Forest; 4.2.2 Arid Swampscrub; 4.2.3 Arid Marshland; and 4.2.4 Arid Strandland.

4.2.1 Arid Swamp Forest

This community has an overstory of trees over 6 meters high. There is often a shrub and herbaceous understory within this category. Cottonwoods (Populus spp.) and sycamores (Platanus spp.) are typical dominants within this category.

4.2.2 Arid Swampscrub

The dominant vegetation within this category consists of low trees or shrubs below 6 meters in height. Willows (Salix spp.) and alder (Alnus spp.) are common dominants within this category.

4.2.3 Arid Marshland

Wetland communities in which the principle plants are herbaceous emergents which have their basal portions annually, periodically, or continually submerged. Examples of dominant vegetation in this category would be cattails (Typha spp.), reed (Phragmites spp.), and bulrush (Scirpus spp.). At the edge of these communities there is often some intermingling of nearby upland species. In addition to the emergent plants, aquatic bed vegetation such as pondweed (Potamogeton spp.) are often present. These areas are often associated with fairly extensive bodies of standing water.

4.2.4 Arid Strandland

The dynamic nature of these communities precludes the establishment of perennial vegetation, although annuals occasionally are found. The surface of these areas often consists of sand or cobbles. Examples of these communities include desert washes, and beach areas within an arid context. Beach and river channel communities subject to infrequent but periodic submersion, wind driven waves and/or spray are also included. Plants are separated by significant areas devoid of perennial vegetation[1] (Brown et al., 1979).

5.0 Snow/Ice

This category includes areas that are covered with snow or ice. Anderson et al. (1976) defines snow and ice in the following way:

> Certain lands are covered either seasonally or have a perennial cover of either snow or ice. A combination of environmental factors cause some of these areas to survive the summer melting season, while in other areas the snow and ice melt to reveal another category or type of land cover.

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[1]Strand communities are situated in harsh physical environments that produce their characteristic physiognomy. Accordingly, strandland is treated as the wetland equivalent of desert land. While occurring in the usual sense on beaches and other seacoast habitats, freshwater (or interior) strands also occur in river channels, along lake margins, and below reservoir high water lines (Brown et al., 1979).

This category is not subdivided into Level II categories, rather it is subdivided at Level III.

5.1 Snow/Ice

This category is subdivided into two Level III categories.

5.1.1 Snow

This category includes all areas which are covered with snow.

5.1.1 Ice/Glacier

This category refers to those areas that are permanently covered with ice as well as glaciers. Ice and superficial snow persists throughout the year and flows downhill under its own weight.

WATER

The Water Division contains all areas that are covered either permanently or semi-permanently covered by water as the primary substrate. There is only one Level 1 category: 6.0 Water and Submerged Land.

6.0 Water and Submerged Land

This category contains areas representing standing and deep water, either natural or man-made. The single feature of this category is that the soil or substrate is saturated with and covered by water. Man-made areas of water would include reservoirs, impoundments, diked areas, ponds, and canals. The Water and Submerged Land category is subdivided into three Level II categories: 6.1 Ocean; 6.2 Coastal; 6.3 Near-Shore; and 6.4 Inland.

6.1 Ocean

This category contains those marine waters which extend seaward from the land and coastal region. Waters with relatively high salinities also exist in this category. The category does not include bays or estuaries that extend inland, for these are included under Coastal. Examples are: the Atlantic Ocean, Pacific Ocean, Gulf of Mexico, and the Arctic Ocean.

6.2 Coastal

Coastal waters include bays, estuaries, and lagoons which lie between terrestrial and marine environments. Sheltered water bodies behind barrier beaches, and tidal mudflats are examples of this type of environment. The water regime in these areas include marine and estuarine. Examples of these areas would be Chesapeake Bay, Puget Sound, or San Francisco Bay.

6.3 Near-Shore

Includes the zone which lies between the normal high water mark and the extent of the emergent and floating vegetation into the open water.

6.4 Inland

This category includes ponds, lakes, reservoirs, streams, and rivers that are not considered coastal or ocean. The water is most often fresh but may be brackish or highly saline (Great Salt Lake).

OTHER

The categories included in this division appear both over Land and Water. There is only one Level 1 category under the division: 7.0 Other.

7.0 Other

The Other category contains unidentified resources or anomalous data which can not be interpreted to fit into any of the land cover categories or water above. This category is divided into:

7.1 Cloud

Clouds that are present in the imagery that obscure land cover categories that exist underneath them. This area also contains hazed areas where the land cover categories are obscured.

7.2 Shadow

Shadows obscure the land cover categories underneath them. The shadows may be caused by clouds or terrain.

7.3 Missing

This category includes any imagery that may be missing due to data drop out, striping of data, or other anomalies in the data set.

7.4 Indeterminable

This category includes those areas that cannot be identified with remote sensing sources due to conditions such as fire. These categories could be spectral clusters that contain only a few pixels, or may be large clusters that contain a wide variety of land cover resources.

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