DATA COLLECTION PLAN FOR REMOTE SENSING IN THE PANHANDLE OF TEXAS, ASVT TEST SITE 2

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The Texas Natural Resources Information System

and

The National Aeronautics and Space Administration

TDWR/TNRIS IAC No. (80-81)-0715

June 13, 1980

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1.0 INTRODUCTION

1.1 Scope

This document describes a ground and aircraft data collection plan to be carried out as part of the Texas Applications System Verification and Transfer (ASVT) Project, which is a joint effort of the Texas Natural Resources Information System (TNRIS) Task Force and the National Aeronautics and Space Administration (NASA). The Texas Department of Water Resources/TNRIS has contracted with the Bureau of Economic Geology for the preparation of this Data Collection Plan (DCP), to be initially implemented during the period June-August 1980 as described herein. This DCP applies to a test site in the Panhandle of Texas (fig. 1) which is one of five test sites designated within the state. Previously, ground data collection plans were prepared for the coastal test site (Finley, 1978), and for the Trans-Pecos test site (Finley and Baumgardner, 1980).

1.2 Test Site Objectives

The economy of the region within this test site (fig. 1) is based to a large extent on agriculture. The productivity of much of the croplands is dependent upon irrigation water (Blackstock, 1979, Table 3). Dryland farming does not use irrigation water, and can be severely affected by drought. Therefore, it is important that the Texas Department of Water Resources (TDWR) has current information regarding the acreage of irrigated crops and the severity of drought conditions in the region.

Playa lakes are common features on the High Plains. Useful as temporary storage facilities for runoff, they appear to be aligned and are the subject of a study of lineaments using Landsat data (Finley and Gustavson, in review) (fig. 2).

The presence of springs along the eastern Caprock Escarpment may be influenced by the withdrawal of ground water from the Ogallala Formation on the High

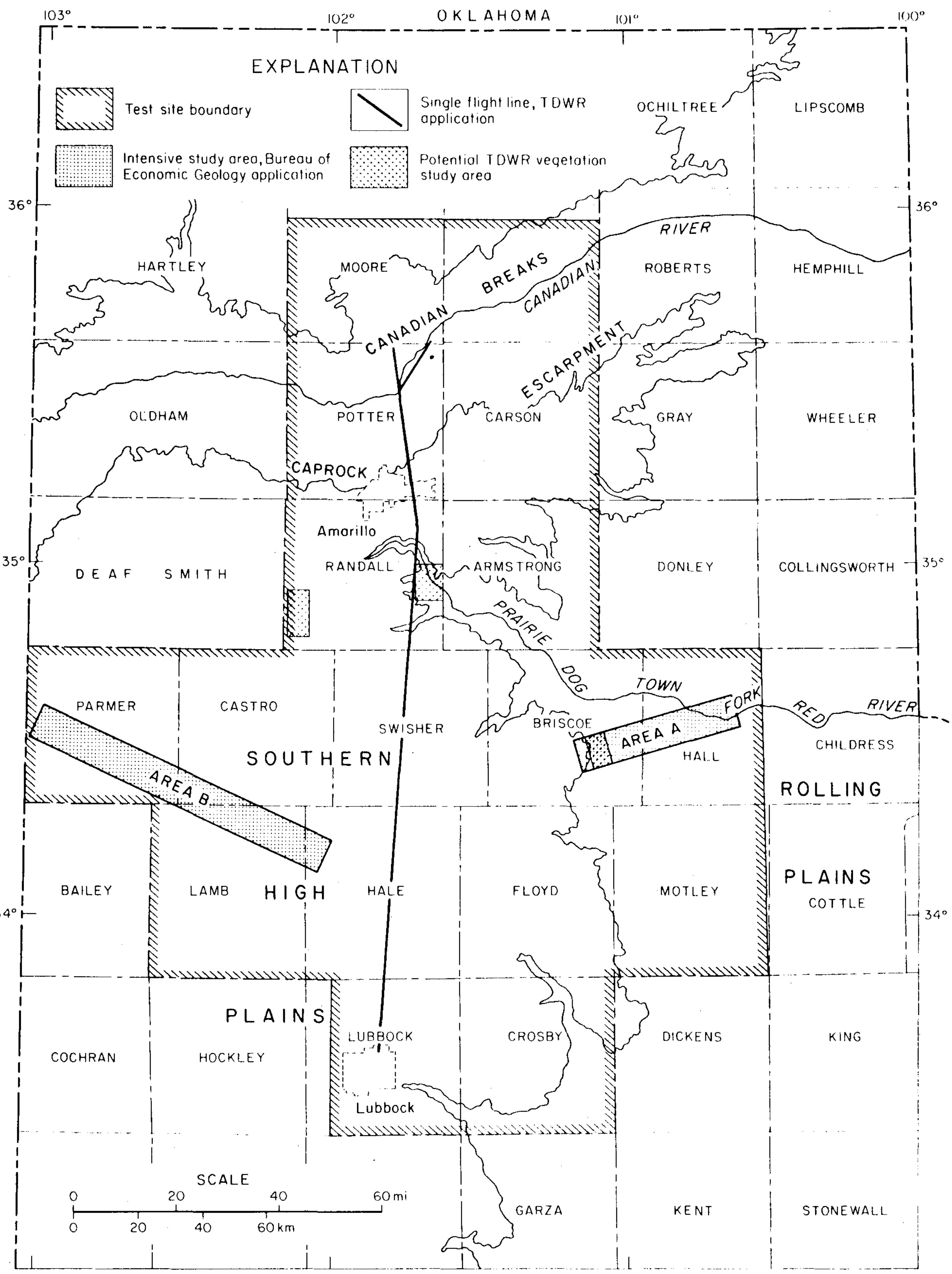

Figure 1. The Texas Panhandle test site.

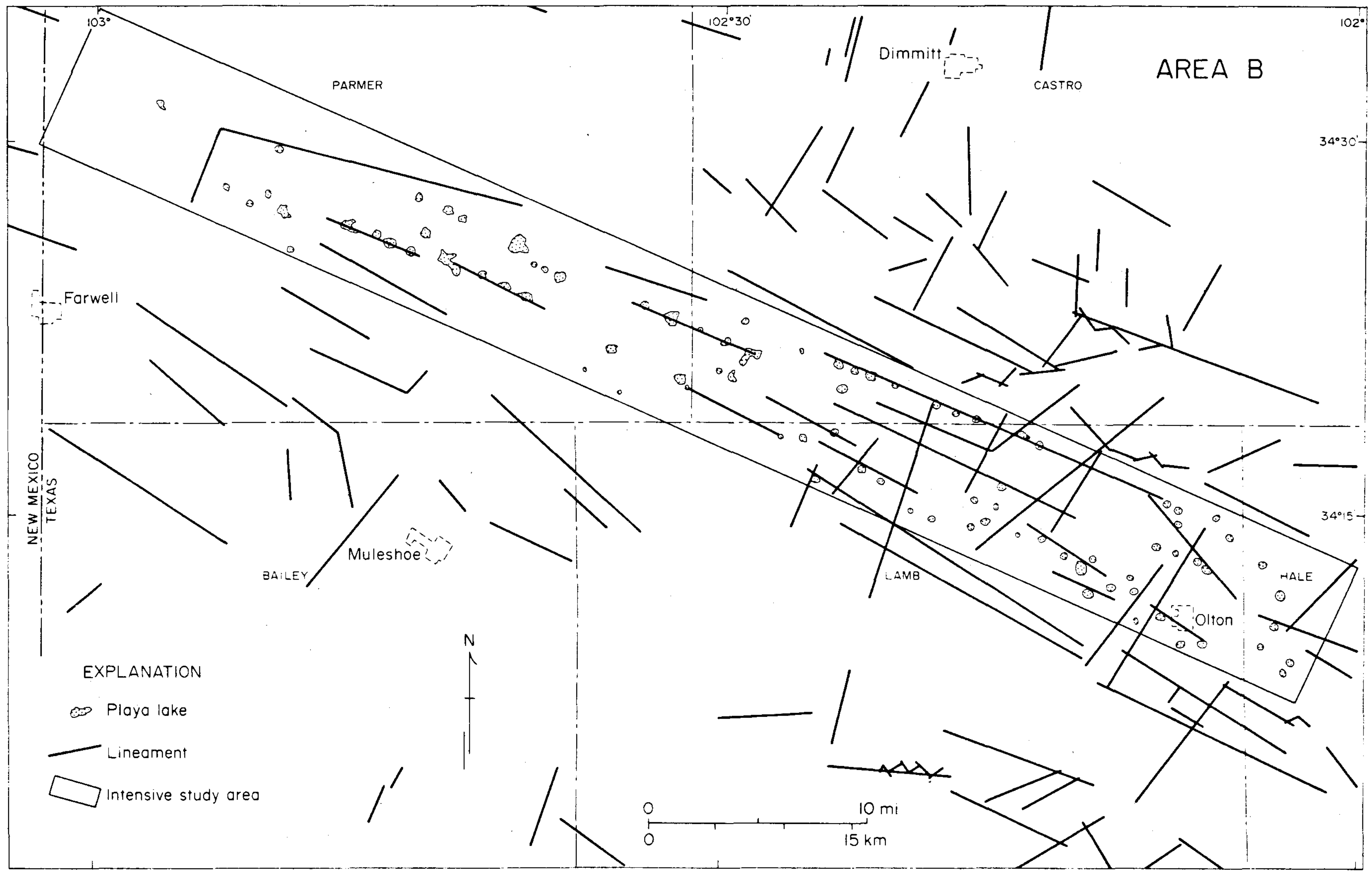

Figure 2. Intensive study area B.

Plains. A change in the number or location of springs might be detected on the thermal infrared channel of the airborne multispectral scanner.

The objectives of this study are to test and apply remote sensing techniques to (1) monitoring drought conditions, (2) detecting irrigated cropland, (3) delineating broad crop categories, (4) detecting lineaments and springs, and (5) distinguishing between various kinds of sedimentary rocks.

Objectives 1-3 are part of the Texas Department of Water Resources' effort to gather timely, accurate information regarding water usage and requirements in northwest Texas. Objectives 4 and 5 comprise an important part of ongoing research at the Bureau of Economic Geology (BEG).

1.3 The Panhandle Test Site

The Panhandle test site covers 14 counties and an area of 40,000 km^2 (15,000 mi^2). The test site spans two physiographic provinces: the Southern High Plains and the Rolling Plains (fig. 1). Within the test site, from Lubbock County on the south to Armstrong County on the east, these two provinces are separated by the steep walls of the Caprock Escarpment. Northwest of Armstrong County the boundary is more transitional.

The High Plains surface is typically very flat, sloping gently toward the southeast at a gradient of about 2 m/km (10 ft/mi). Most runoff collects in playas, and, if not used for irrigation, either evaporates or percolates into the underlying sediments. The amount of water in a playa is a function of the size of its catchment, the permeability of the bottom sediments, evaporation, and, of course, precipitation.

The geology of the test site area is not complex. Flat-lying sedimentary rocks underlie the High Plains surface which is covered with a mantle of variable thickness composed mostly of windblown sand (Barnes, 1967, 1968, 1969, 1978). Resistant sandstone and conglomerate within the Ogallala Formation and the Dockum Group form the steep walls and cliffs which comprise the Caprock Escarpment. Below the

Escarpment, Permian-age siltstones and sandstones of the Whitehorse and Quartermaster Formations erode to develop the low hills of the Rolling Plains.

Most of the region's precipitation, which varies from 380-530 mm (15-21 in) annually, falls during the period April to September (Gould, 1969). During this time, most rain falls during thunderstorms. Native vegetation on the High Plains is dominated by grasses. However, much of the region has been converted to agricultural use for raising row crops such as cotton and corn, and small grains, such as wheat.

Along the escarpment native vegetation is dominated by juniper. Sandy lands, such as the sand hills in Lamb County, are populated with shinnery oak and sage, and yucca and mesquite have invaded some of the High Plains (Gould, 1969).

Soils of the region range from loamy fine sand on uplands to clay in playa bottoms. Soil thickness ranges from less than three to more than 7 ft (Blackstock, 1979).

1.3.1 Test Site Intensive Study Areas

The intensive study areas described below were chosen to satisfy the requirements of the Texas Department of Water Resources and the Bureau of Economic Geology. Each site is discussed under the heading of the agency for which it serves its primary purpose, although both may conduct investigations there.

1.3.1.1 Texas Department of Water Resources

1.3.1.1.1 Palo Duro Canyon

Palo Duro Canyon is located in eastern Randall County, Texas (fig. 1), 19 km (12 mi) east of Canyon, Texas. It is the largest canyon along the eastern Caprock Escarpment. The upper part of the canyon is maintained as a state park, and most of it is in native vegetation. The plateau in the center of the park, Mesquite Park, has a uniform vegetation cover and can be used for monitoring drought stress of native vegetation.

1.3.1.1.2 Buffalo Lake

Buffalo Lake is located in southwestern Randall County, Texas (fig. 1), 21 km (13 mi) southwest of Canyon, Texas. The lake and the area surrounding it were maintained as a national wildlife refuge until early 1980 when the lake was drained owing to damage sustained by the dam during severe flooding in May, 1978. The vegetation within the refuge boundaries is composed mostly of native grasses. This area, because it is adjacent to cultivated land, provides a means of comparing drought stress of native vegetation with that of cash crops.

1.3.1.1.3 Lake Meredith

The land/water boundary at the upstream end of Lake Meredith is an ideal target for monitoring the lake's level, which responds to inputs by precipitation and runoff and outputs via evaporation and drawdown. Extensive areas of rangeland around the lake also provide the TDWR with a natural laboratory for drought inventory.

1.3.1.1.4 C-130 Flight Line; Lubbock-Lake Meredith, Buffalo Lake

The C-130 flight will provide aerial photography of a strip of land 6.8 km (4.25 mi) wide extending from Lubbock to Lake Meredith (fig. 1). Buffalo Lake will also be photographed. Most of the land cover/land use categories in the High Plains are covered by this flight line including irrigated and nonirrigated cropland, as well as prairie grassland and rangeland. The airports at Lubbock, Plainview and Amarillo are included in the C-130 flight line; data from these localities are used to calculate the Palmer Index, a measure of drought conditions.

1.3.1.2 Bureau of Economic Geology

1.3.1.2.1 Area A - Little Red River Basin

The Little Red River has its headwaters at the eastern Caprock Escarpment (fig. 1). Springs flow into the channel at numerous points along the stream. A representative section of the regional geology from Permian redbeds to Tertiary sandstones is exposed in the river basin.

Juniper is the dominant woody shrub, although mesquite is also present. Cottonwoods are found in the upper part of the canyon on floodplains. Prickly pear and yucca are common, and the grass cover varies depending on slope and aspect.

Geologic studies have located one major spring along the Little Red River; other springs may be detectable on thermal infrared imagery derived from the airborne multispectral scanner. These springs will later be sampled as part of an evaluation of the hydrology of the Palo Duro basin. Side-looking airborne radar data and airborne multispectral scanner imagery will be applied toward mapping of gently flexed rock units, which have been deformed by salt dissolution at depth. Fracture control of some of this deformation may be evident.

1.3.1.2.2 Area B - Running Water Draw Lineament

This intensive study area contains abundant lineaments, or linear physiographic features. Playas are aligned in a NW-SE direction (fig. 2). This area was chosen because it contains a very high lineament density, and shows some of the best aligned playas on the High Plains. The alignment of these playas is most likely controlled by jointing. The playas themselves may be localized at the intersections of zones of greater joint density. The shallow swales connecting existing playas appear to be incipient drainages that are also controlled by jointing. Because the High Plains surface is at extremely low relief it is desirable to acquire SLAR data to define as yet undetected lineaments and further evaluate geologic controls of their orientation.

1.4 Objective of Surface Observations

Surface observations will provide collateral data that will assist in developing classification techniques for use with the remote sensor data. Data regarding vegetation types in the areas of native flora will be used to select suitable sites for drought monitoring. Observations of irrigated versus nonirrigated cropland, canopy cover, planting pattern and soil moisture will be used to design a classification scheme for the detection of irrigated cropland. Because of the ephemeral nature of some of these conditions, ground observation by personnel of the TDWR is planned to coincide with the satellite overpass and/or the C-130 aircraft overflight

For purposes of geologic mapping and the detection of lineaments, surface observations need not coincide with the satellite or aircraft overpasses. Personnel from BEG will be in Area A soon after the satellite overpasses on June 17 and 18 and will be able to document the location of any springs in the area.

Further activities in support of the surface observation objective are listed in Section 2.3.

2.0 DATA REQUIREMENTS AND ACQUISITION

A selection of Landsat products will be utilized by the ASVT Project Team as part of analysis of the Panhandle test site. These requirements are outlined here, as is the need for surface and airborne data.

2.1 Landsat Data Requirements

Landsat data are to be provided by Landsat-3, with four bands of Multispectral Scanner (MSS) data, and by four Return Beam Vidicon (RBV) images corresponding to each Landsat scene over the test site. Parts of four scenes will be required to cover the north and central parts of the test site; parts of two additional scenes may be needed to cover the southern margin of the test site (fig. 3). All Landsat products will be sent to TNRIS for indexing, storage, and retrieval to support the ASVT Project Team.

MSS Products

(1) Computer-compatible tapes, all data

(2) Black-and-white positive transparencies, 1:1,000,000 scale, all bands

(3) FCC positive transparency, 1:1,000,000 scale

(4) FCC paper print, 1:250,000 scale

(5) Black-and-white paper prints, 1:250,000 scale, bands 5 and 7

(6) Black-and-white positive transparencies, 1:3,369,000, all bands

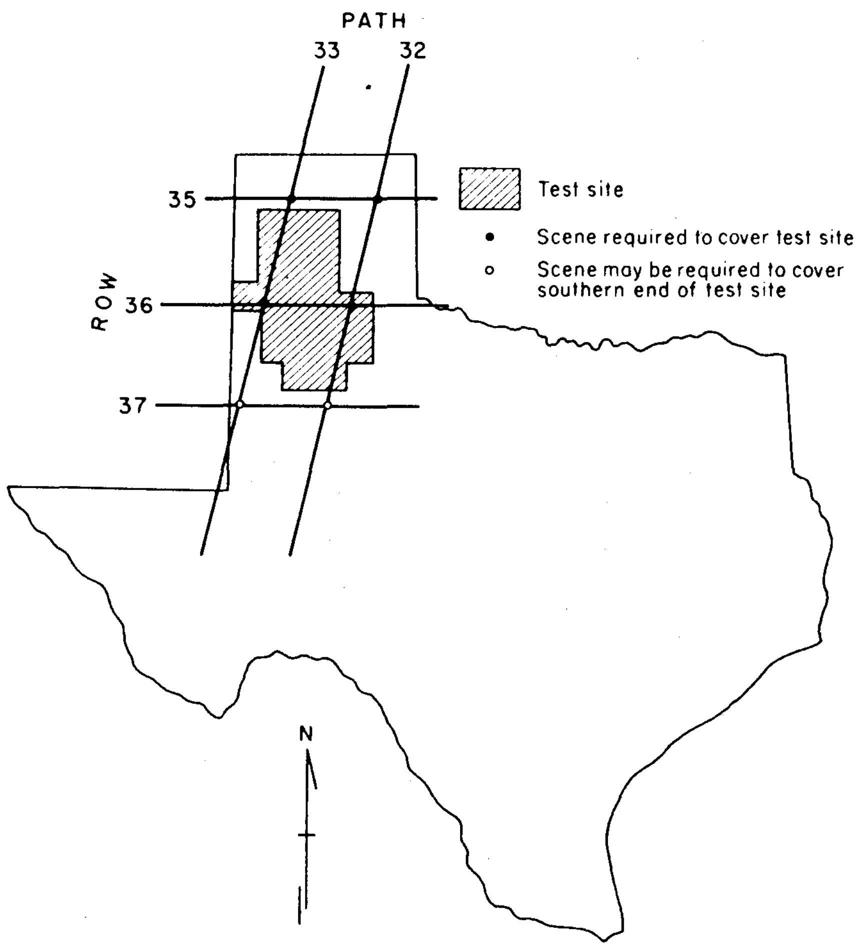

Figure 3. Path/row index map for Landsat scenes covering parts of the Panhandle test site.

RBV Products

(1) Black-and-white positive transparency, 1:500,000 (four for each MSS scene where coverage includes part of the test site)

(2) Black-and-white negative transparency, 1:500,000 (four for each MSS scene where coverage includes part of the test site)

(3) Black-and-white positive paper prints, 1:125,000 or as large a scale as available (four for each MSS scene where coverage includes part of the test site)

The following schedule of Landsat-3 overpasses will cover parts of the Panhandle test site:

Path 32	Path 33
June 17, 1980	June 18, 1980
July 5, 1980	July 6, 1980
July 23, 1980	July 24, 1980
August 10, 1980	August 11, 1980

2.1.1 Landsat Data Acquisition

Landsat products defined above will be obtained by TNRIS through the EROS Data Center.

2.2 Aircraft Data Requirements and Acquisition

Aerial photography is an effective means of providing natural resource information at large scales and high resolution and of aiding in the analysis of small-scale, low-resolution Landsat data. Aircraft data are required to (1) support the development of analysis techniques within the Remote Sensing Information Subsystem (RSIS), (2) evaluate other sensor systems and components, such as NS-001 scanner data and higher resolution RBV imagery, (3) determine the optimum mix of aircraft and satellite data that will meet the resource information needs of state agencies, and (4) develop and carry out an evaluation of Landsat-derived classification products using aerial photography in conjunction with ground data and published information.

The primary aircraft support will be provided by NASA, utilizing cameras and scanners as outlined below.

2.2.1 NASA Aircraft

NASA aircraft will obtain aerial photographs of the entire Panhandle test site, scale of 1:120,000, and along the single flight line, over Areas A and B, and over Buffalo Lake (fig. 1) at a scale of 1:30,000. Multispectral scanner data will be obtained in conjunction with the photography. All imagery and scanner data will be titled and indexed in accordance with standard NASA procedures to show the location and extent of coverage.

2.2.2 Sensor Parameters

The NASA aircraft data acquisition will be governed by the following requirements and constraints:

(1) High-Altitude Data Acquisition (1:120,000)

Aircraft: RB-57 at 18,288 m (60,000 ft) altitude

Area of coverage: Entire test site (fig. 1)

Sensors: Zeiss 152-mm (6-inch) focal length camera with color film (EK Type SO-397, haze filter)

Zeiss 152-mm (6-inch) focal length camera with color-IR film (EK Type 2443, Wratten No. 12 filter)

Side-looking Airborne Radar data will be acquired over Areas A and B

RS-18 scanner simultaneous with photography

Overlap: 60% forward overlap and 30% sidelap over total area with Zeiss cameras

Permissible cloud cover: 20% maximum

(2) Low-Altitude Data Acquisition (1:30,000)

Aircraft: C-130 at 4,572 m (15,000 ft) altitude

Area of coverage: Three areas within the test site (fig. 1)

Sensors: Zeiss 152-mm (6-inch) focal length camera with color film (EK Type SO-397, haze filter)

Zeiss 152-mm (6-inch) focal length camera with color-IR film (EK Type 2443, Wratten No. 12 filter)

NS-001 scanner is mandatory in 0.63-0.69, 1.55-1.75, 2.08-2.35, and 10.4-12.5 micron bandwidths; other bandwidths are highly desirable

Overlap: 60% forward overlap along flight line with Zeiss cameras

Permissible cloud cover: Maximum of 10% within flight line area

Table 1 lists bandwidths associated with three airborne multispectral scanners that may be utilized for data collection. The NS-001 scanner is to be used exclusively in the C-130 because the 1.55 to 1.75- and 2.08 to 2.35- micrometer bandwidths are needed for geologic applications. It is recognized that the RS-18 scanner cannot be operated for low-altitude data acquisition. Radiometer data are to be collected along flight lines to aid in calibration of the thermal infrared channel of the multispectral scanners.

2.2.3 Aircraft Deployment

The flight window for the C-130 and RB-57 aircraft is June 16, 1980, through July 11, 1980. The second flight window, if needed, begins August 25, 1980. There are no requirements for these aircraft to synchronize operations either with each other or with the Landsat-3 overpass. Experience in the area indicates that cumulus cloud build-up often begins around noon if it is to occur. The early part of the usual 10 a.m. to 2 p.m. data acquisition period is therefore likely to be the most favorable.

2.2.4 NASA Aircraft Data Products

The following products are to be supplied by NASA to TNRIS for indexing, storage, and retrieval to support the ASVT Project Team:

Table 1. MSS Sensors and Bandwidths (in microns), available at NASA/JSC for aircraft operations.[1]

NS-001	M²S	RS-18
.45 - .52	.38 - .44	.5 - .6
.52 - .60	.44 - .49	.6 - .7*
.63 - .69*	.49 - .54	.7 - .8
.76 - .90	.54 - .58	.8 - .9
1.00 - 1.30	.58 - .62	10.0 - 12.0
1.55 - 1.75	.62 - .66*	
2.08 - 2.35	.66 - .70	
10.4 - 12.5	.70 - .74	
	.76 - .86	
	.97 - 1.06	
	8.05 - 13.7	

[1]Bands indicated with an asterisk (*) will be provided to ASVT Project Team as black-and-white positive transparencies (and as negatives) for data review purposes.

(1) Two second-generation color positive transparencies derived from all color and color infrared original rolls.

(2) One second-generation black-and-white positive transparency of selected bands (see table 1) of multispectral scanner data, as well as one set of negatives for the same data.

(3) Digital scanner data, in computer-compatible tape format (Universal JSC format).

(4) Indexes to all imagery and data showing the location and extent of coverage.

(5) Copies of mission logs and any associated materials that help to define mission parameters and existing conditions (e.g., weather, time of day, etc.).

2.2.5 State Agency Aircraft

The Texas General Land Office (GLO) operates a twin-engine Beechcraft Baron with a Fairchild camera and a 152-mm (6-inch) focal length lens. This aircraft will be available should additional, large-scale photography be required of specific locations within the test site. Such a requirement could arise during data analysis. This aircraft will not be operated during initial data acquisition.

2.3 Surface Data Requirements and Acquisition

2.3.1 Project Team Observations

As in the Coastal Applications Test Site (Finley, 1978), some project team observations are needed in conjunction with the Landsat overpass. Personnel from the Agriculture Unit of the Planning and Development Division of TDWR will map irrigated and nonirrigated cropland, crop types, planting patterns and canopy cover coincident with one of the satellite overpasses. Personnel of the National Weather Service in Lubbock and Amarillo will provide cloud cover observations and other meteorologic data on the days of the overpasses.

The plant surveys will be conducted by personnel from the Austin and Amarillo offices of the TDWR.

An Exotech brand hand-held radiometer will be available for observing relative reflectance of various substrate and vegetation types, if this is necessary. The device utilizes the same four spectral channels as does the Landsat MSS. Results will be useful in refining the delineation of different substrate and substrate-vegetation mixes from Landsat and airborne MSS data. Most observations on the ground can be made on public parklands or along public roads.

2.3.2 Observations at Existing Facilities

At present it is not anticipated that observations at existing facilities will be required to evaluate Landsat imagery over the test site other than to review rainfall in the few days before the overpass. Such a review is required if tonal differences owing to varying soil moisture are noted on any of the remote sensing data.

2.3.3 Weather Data

Weather data are available from NWS stations at Amarillo and Lubbock, as well as Childress, just east of the test site, and Dalhart, northwest of the test site. Daily rainfall is recorded at a number of localities within and adjacent to the test site, including five recording rain gages maintained by the Bureau of Economic Geology.

2.3.4 Published Reports

The bibliography attached to this plan includes additional publications about the geology, botany, and meteorology of the area. Also included are references to processing of remote sensing data for geologic, water resource evaluation, and vegetation inventory applications. These publications are under review to help develop the appropriate processing procedures for data from the Panhandle site.

3.0 References

Barnes, V. E., 1967, Geologic Atlas of Texas, Lubbock Sheet: The University of Texas at Austin, Bureau of Economic Geology.

_______ 1968, Geologic Atlas of Texas, Plainview Sheet: The University of Texas at Austin, Bureau of Economic Geology.

_______ 1969, Geologic Atlas of Texas, Amarillo Sheet: The University of Texas at Austin, Bureau of Economic Geology.

_______ 1978, Geologic Atlas of Texas, Clovis Sheet: The University of Texas at Austin, Bureau of Economic Geology.

Blackstock, D. A., 1979, Soil survey of Lubbock County, Texas: U.S. Department of Agriculture, 105 p.

Finley, R. J., 1978, Remote sensing data collection plan, test site 1 (coastal), Texas Natural Resources Inventory and Monitoring System, Applications System Verification and Transfer: Austin, Texas Natural Resources Information System, 56 p.

Finley, R. J., and Baumgardner, R. W., Jr., 1980, Data collection plan for geological remote sensing in the volcanic terrain of Trans-Pecos Texas, ASVT Test Site 5: The University of Texas at Austin, Bureau of Economic Geology, 22 p.

Finley, R. J., and Gustavson, T. C., in review, Landsat lineament analysis of the Texas Panhandle: Photogrammetric Engineering and Remote Sensing.

Gould, F. W., 1969, Texas plants, a checklist and ecological summary: Texas A&M University, Texas Agriculture Experiment Station, MP-585/Revised, 119 p.

4.0 Bibliography

Ashley, M. D., and Rea, J., 1974, Densitometry of ERTS-1 imagery to access vegetation change, in Shahrokhi, F., ed., Remote sensing of earth resources, v. 3: University of Tennessee at Tullahoma, Space Institute, p. 297-317.

Bell, A. E., and Sechrist, A. W., 1972, Playas, Southern High Plains of Texas, in Reeves, C. C., Jr., ed., Playa Lake Symposium: Texas Tech University, International Center for Arid and Semi Arid Land Studies, Publication 4, p. 35-39.

Boland, D. H. P., and Blackwell, R. J., 1975, The Landsat-1 multispectral scanner as a tool in the classification of inland lakes: Houston, NASA earth resources survey symposium, v. 1-A, p. 419-442.

Conn, J. S., Foster, K. E., and McGinnies, W. G., 1975, The nature of spectral signatures in native arid plant communities: Proceedings, American Society of Photogrammetry, Oct. 26-31, 1975, Phoenix, Arizona, p. 876-884.

Crosson, L. S., Peet, F. G., and Read, W. L., 1976, Agricultural crop reflectance studies using Landsat-1 data, in Thompson, G. E., ed., Third Canadian symposium on remote sensing: Edmonton, Alberta, Canadian Aeronautics and Space Institute, p. 427-433.

DeGloria, S. D., Daus, S. J., and Thomas, R. W., 1975, The utilization of remote sensing data for a multidisciplinary resource inventory and analysis within a rangeland environment: Proceedings, American Society of Photogrammetry, Oct. 26-31, 1975, Phoenix, Arizona, p. 640-659.

Dethier, B. E., Ashley, M. D., Blair, B. O., and others, 1975, Satellite sensing of phenological events: Agriculture, v. 6, no. 1, 46 p.

Evans, G. L., and Meade, G. E., 1945, Quaternary of the Texas High Plains: University of Texas, Austin, Bureau of Economic Geology Publication 4401, p. 485-507.

Frye, J. C., 1970, The Ogallala Formation - a review, in Maltox, R. B., and Miller, W. P., eds., Ogallala aquifer symposium: Texas Tech University, International Center for Arid and Semi-Arid Land Studies, Publication 4, p. 5-14.

Hancock, K. J., and Schlosser, E. H., 1975, Landsat, a satellite surface water divining rod: Proceedings, American Society of Photogrammetry, Oct. 26-31, 1975, Phoenix, Arizona, p. 375-380.

Harris, B. L., and others, 1972, Mineralogical and selected chemical properties of High Plains playa soils and sediments, in Reeves, C. C., Jr., ed., Playa lake symposium: Texas Tech University, International Center for Arid and Semi-Arid Land Studies, Publication 4, p. 287-299.

Heller, R. C., 1978, Case applications of remote sensing for vegetation damage assessment, in Proceedings, Symposium on remote sensing for vegetation damage assessment, Seattle, Washington, February 14-16, 1978: Falls Church, Virginia, American Society of Photogrammetry, p. 231-252.

Hundemann, A. S., 1977, Remote sensing applied to geology and mineralogy (a bibliography with abstracts): Springfield, Virginia, National Technical Information Service, NTIS/PS-77/0676.

Idso, S. B., Pinter, P. J., Jr., Jackson, R. D., and Reginato, R. J., 1980, Estimation of grain yields by remote sensing of crop senescence rates: Remote Sensing of Environment, v. 9, p. 87-91.

Levine, S., 1976, Correlation on ERTS spectra with rock/soil types in Californian grassland areas: Proceedings, International symposium on remote sensing of environment, 10th, Ann Arbor, Michigan, p. 975-984.

Morain, S. A., Budge, T. K., and White, M. E., 1977, Vegetation and land use in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Resource Map 8, scale 1: 1,000,000.

Murtha, P. A., 1978, Remote sensing and vegetation damage - a theory for detection and assessment, in Proceedings, Symposium on remote sensing for vegetation damage assessment, Seattle, Washington, February 14-16, 1978: Falls Church, Virginia, American Society of Photogrammetry, p. 19-52.

Odle, W. C., 1976, Remote sensing of St. Augustine decline (SAD) disease: Texas A&M University, Ph.D. dissertation, and Remote Sensing Center, TR-RSC-77, 177 p.

Richardson, A. J., and Wiegand, C. L., 1977, Criteria for distinguishing vegetation from soil background information and their use in processing Landsat MSS data; Appendix B, soil, water and vegetation conditions in South Texas: U.S. Department of Agriculture, Agricultural Research Survey, Final Report, 52 p.

Robinson, J. E., and Carroll, S., 1976, Enhancing of geological definition in Landsat data, in Thompson, G. E., ed., Third Canadian symposium on remote sensing, Edmonton, Alberta, September 1975: Ottawa, Canadian Aeronautics and Space Institute, p. 145-153.

Sikes, S., and Smith, J., 1975, A vegetational study of the Canadian River Breaks, in Kennard, D., project director, Canadian Breaks, a natural area survey: The University of Texas at Austin, Division of Natural Resources and Environment, p. 46-58.

Sinnock, S., Melborn, W. N., and Montgomery, O. L., 1974, Machine-aided analysis of land use-landform relations from ERTS-1 MSS imagery, Sand Hills region, Nebraska, in Shahrokhi, F., ed., Remote sensing of earth resources, v. 3: University of Tennessee at Tullahoma, Space Institute, p. 503-527.

Tucker, C. J., Elgin, J. H., Jr., McMurtrey, J. E., III, and Fan, C. J., 1979, Monitoring corn and soybean crop development with handheld radiometer spectral data: Remote Sensing of Environment, v. 8, p. 237-248.

Tucker, C. J., and Miller, L. D., 1974, Extraction of underlying soil spectra from canopy spectroreflectance measurements of the shortgrass prairie, in Shahrokhi, F., ed., Remote sensing of earth resources, v. 3: University of Tennessee at Tullahoma, Space Institute, p. 73-83.

Webb, K., High, C. J., and Coiner, J. C., 1976, Application of Landsat data to agricultural resource problems with emphasis on North American Great Plains: Columbia University, NASA Progress Report N76-29669, 34 p.

Wyatt, A. W., Ellis, M. L., and Bell, A. E., 1975, The application of remote sensing technology to the inventory of playa lakes in the High Plains of Texas: Houston, NASA earth resources survey symposium, v. 1-D, p. 2523-2530.

Yarger, H. L., and McCauley, J. R., 1975, Quantitative water quality with Landsat and Skylab: Houston, NASA earth resources survey symposium, v. 1-A, p. 347-370.